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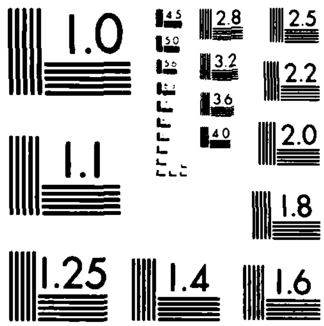

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CARBURETOR CLEANLINESS TEST PROCEDURE STATE-OF-THE-ART SUMMARY REPORT: 1973 - 1981

April 1983

COORDINATING RESEARCH COUNCIL, INC.
219 PERIMETER CENTER PARKWAY, ATLANTA, GEORGIA 30346

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COORDINATING RESEARCH COUNCIL
INCORPORATED
219 PERIMETER CENTER PARKWAY
ATLANTA, GEORGIA 30346
(404) 396-3400

CARBURETOR CLEANLINESS TEST PROCEDURE
STATE-OF-THE-ART SUMMARY REPORT: 1973 - 1981

(CRC PROJECT No. CM-97-71)

Prepared by the

Carburetor Test Procedure Panel

of the

Fuels and Engine Cleanliness Group

DAAK-70-81-C-0128

April 1983

Light-Duty Vehicle Fuel, Lubricant, and Equipment Research Committee

of the

Coordinating Research Council, Inc.

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I. BACKGROUND

In June 1971, responding to a joint industry request from the API/ASTM/SAE Ad Hoc Task Force on National Gasoline Performance and Information System, the Coordinating Research Council (CRC) Light-Duty Fuels and Engine Cleanliness Group was organized to investigate the effects of automotive fuels on engine deposits with respect to emissions and durability. Since no industry-wide engine tests were then available to evaluate the effects of fuels on engine deposits, four panels* were set up to develop engine and bench test procedures, and to gather and evaluate field performance data. Subsequent to the organization of the four panels, the concept of a gasoline performance and information system to be posted on the gasoline pump was dropped; however, the work of the panels continued in anticipation of the future need for engine test procedures to evaluate fuel performance.

This report summarizes a nine-year effort of the Carburetor Test Procedure Panel of the CRC Light-Duty Fuels and Engine Cleanliness Group to develop a viable engine test procedure to evaluate the effect of automotive fuels on carburetor cleanliness. Members at the start of the program and current members are listed in Appendix A.

II. OBJECTIVE

The objective of the Carburetor Test Procedure Panel was to develop a viable laboratory engine test procedure for evaluating the effect of gasolines on the formation of deposits in the throttle body area of carburetors.

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* Carburetor Test Procedure Panel
Intake Manifold Deposit Bench Test Procedure Panel
Intake Manifold Deposit Engine Dynamometer Test Procedure Panel
Intake Manifold Deposit Vehicle Test Panel

III. SUMMARY

Initially, an extensive study by the Panel of the current laboratory procedures and related information in this area was undertaken. From the study, a tentative proposal for a carburetor cleanliness test was established even before a test engine was selected. The procedure was to be developed with the use of a removable carburetor throttle bore sleeve. Test evaluation criteria were related to the deposit buildup and visual rating of the sleeve. The engine emission levels during the test were also characterized as possible evaluation criteria, but were never fully developed as such.

Eight procedure drafts were written and distributed for test development. The first four drafts were mainly concerned with leaded fuel severity and results. The remaining procedures emphasized changes for unleaded fuel testing and for improving test repeatability and reproducibility. Over 750 tests utilizing the procedure drafts were reported to the Panel. Of the 750 reported tests, 66 percent were unleaded fuel runs.

Five controlled test programs were completed by the Panel. Programs were used to investigate and validate changes and drafts in the test procedure on severity. A carburetor round-robin program investigated the possible reproducibility effects as related to the carburetor and found that other engine and procedure variables were superseding the carburetor effect. An unleaded fuel correlation program utilizing six fuels proved that the procedure could be used to rank fuels in essentially the same order by the nine participating laboratories.

Several of the test programs found repeatability of the procedure acceptable, but reproducibility among laboratories was usually poor.

A subpanel developed a proposed carburetor rating procedure which was recommended as a CRC procedure.

IV. RECOMMENDATIONS

The current carburetor test procedure (Appendix B), or modifications thereof, has been used by participating laboratories of the Panel and others for in-house carburetor cleanliness evaluations for several years. The procedure has proven to be an effective laboratory tool for screening fuels and/or fuel additives. In general, the Panel members have found the repeatability of the procedure to be acceptable.

Reproducibility of the procedure among participating laboratories has been poor. Although control of test equipment and procedure has been tightened, the Panel's recommendation is that better control of test engine, equipment, and operating conditions must be obtained to improve reproducibility to an acceptable level.

- The Carburetor Test Procedure Panel recommends that the Proposed Carburetor Rating Procedure (Appendix C), which was developed by a subpanel within the Panel, be approved as a CRC rating method.

- Carburetor deposit levels have been satisfactory with leaded gasolines and the procedure appears to separate leaded fuels of different cleanliness levels. Deposit levels have been low, however, with some unleaded gasolines such as Phillips J reference fuel. There is some concern that the test may not discriminate among fuel cleanliness additives in these low deposit level fuels. The Panel put considerable effort into increasing test severity (more deposits) to maintain a reasonable response of reference Additive A in Phillips J fuel with some success. While no formal Panel effort is recommended to increase test severity, individual laboratories with a severity problem may want to consider the following modifications to increase deposit levels:

  -- Increase test length

  -- Increase the proportion of cruise condition relative to idle in the test cycle

  -- Increase EGR valve flow

  -- Increase intake air inlet temperature

- The engines and carburetors with which the procedure was developed are several years old. While the basic components are common to most engines in use, other carburetion techniques for preparing the fuel and air for induction are being introduced. It is therefore recommended that work be continued to update carburetors and engines used in the test procedure as required by future industry needs.

V. DEVELOPMENT OF TEST PROCEDURE

A. Initial Test Procedure Program

1. Initial Group and Panel Organization

In late 1971, the CRC was specifically requested to develop a program to investigate induction system cleanliness. An ad hoc group was formed within the CRC Motor Committee (now CRC Light-Duty Committee) to develop a program proposal.

In early 1972, the ad hoc group sent out a letter requesting information relating to the effect of gasolines on induction system deposits and the effect of these deposits on exhaust emissions and durability. This information was to involve fleet tests, engine dynamometer tests, or laboratory bench tests. Of particular interest were data which would help correlate field experience with laboratory tests. The ad hoc group's plan was to develop techniques to evaluate gasolines as final products. They were also interested in test procedures used to evaluate additive performance.

2. Summary of Existing Procedures

There were nine positive responses reviewed by the ad hoc group, and the responding companies are listed below:

- Amoco Chemical Corporation
- Chevron Research Company
- E.I. DuPont de Nemours & Co.
- Ethyl Corporation
- Gulf Research and Development Co.
- Lubrizol Corporation
- Phillips Petroleum Company
- Rohm and Haas Company
- Texaco Inc.

Most of the procedures submitted (about twenty) utilized engine dynamometers and were concerned with carburetor cleanliness or intake valve and port deposits. There were two general types of carburetor cleanliness tests: keep-clean, and cleanup. There were nine carburetor keep-clean test procedures, three carburetor cleanup procedures, and eight intake valve deposit procedures submitted. Several companies used field tests as a supplement to the engine dynamometer program. The only laboratory bench test suggested was the Induction System Deposit Test (ISD), developed by the US Army Fuels and Lubricants Research Laboratory at Southwest Research Institute. Most of the dynamometer procedures utilized multi-cylinder test engines, but a few used small, single-cylinder engines. The engine operating time to complete a carburetor detergency test averaged 50 hours, and ranged from 1.5 hours to 310 hours. The time required for induction system deposit tests averaged 120 hours and ranged from 30 hours to 220 hours. Most of the procedures increased the severity of deposit formation by artificial means. Some directed engine blowby to above the carburetor, and some introduced exhaust gas to the air cleaner, either from the test engine or from a second "slave" engine. The type of engine operation was predominately light-duty, but there was considerable variety in the modes of operation. Some procedures depended upon visual deposit ratings, while others used removable carburetor sleeves which were weighed before and after deposit accumulation.

3. Approach to Developing a Procedure

The ad hoc group decided that their initial objective should be to develop a new, keep-clean carburetor throttle body test, employing a current-design, multi-cylinder engine operated on an engine dynamometer. It was agreed that the test procedures submitted by the different companies would be considered in the development of this new procedure. A secondary objective would be to develop an intake valve and port-deposit test which, it was hoped, would be complementary to the carburetor keep-clean test.

From this action, working panels were evolved to accomplish the objectives. Before mid-year of 1972, the Carburetor Test Procedure Panel was formally organized and development of the carburetor cleanliness test procedure was begun.

By the end of 1973, the Panel had made initial recommendations in regard to engine type, hardware, test conditions, fuels, and oils, etc.

4. Engine Selection

The Panel selected a six-cylinder engine, which used a single-barrel carburetor instead of a two-barrel carburetor. The engine also had to allow for use of a removable aluminum sleeve in the carburetor throttle bore area to determine deposit weight. Engine manufacturers were asked to recommend and donate test engines for in-house development testing by the Panel. The Ford 1973 model, 240-cubic-inch, six-cylinder engine with an EGR system was selected. Engines were received at laboratories during December of 1972. Initially, eight active laboratories began test development work.

5. Engine Test Conditions

Even before the test engine was selected, a tentative proposal for a carburetor cleanliness test was established. This embryonic state of the procedure was as follows:

TENTATIVE CARBURETOR CLEANLINESS TEST PROPOSAL
BY CRC FUEL/ENGINE CLEANLINESS WORKING GROUP

Engine	Four or six cylinder model to be recommended by engine selection team (V-8 model will not be used as originally decided). Engine to have an EGR system.
Cycle Speed	Test cycle will be two phases, an idle speed and a cruise speed. RPM values to be determined after engine selection.

Cycle Load	Idle 0 lbs Cruise Light load used by some, no load by others
Cycle Time	Idle 7 minutes Cruise 30 seconds
Test Length	20 hours approximately
Intake Air Temp.	Controlled at 100° F
Humidity	80 grains/lb dry air
Air/Fuel Ratio	Set initially at idle (11.5-12.0). The following conditions will be monitored throughout the test: -- Carbon monoxide in exhaust (idle) -- Hydrocarbons (both idle and cruise) -- Fuel flow (both idle and cruise) -- Air flow (throttle setting)
Fuel Flow	Recorded after initial setting
Oil Temp.	Equilibrium condition
Coolant Temp.	195° F (both phases) using a standardized control system (to be determined)
Intake Manifold Vacuum	Record
Exhaust Back Pressure	Standarize values (to be determined)
Means to Dirty Up Carburetor	Use engine blowby and control rate with a calibrated orifice. Blowby will be directed to an empty insulated air cleaner assembly. Blowby rate (cfh) to be determined.
Engine Lubricant	Use an SAE 30 base oil with a 0.10 percent Zn level. Lubricant to be changed every test run. Lubricant will be given an REO number.
Rating Method	Use a removable throttle bore sleeve and determine deposit build up for test run. Test sleeve material would be aluminimum with a standardized surface finish. A visual rating method of sleeve deposits will be established.

Throttle Base Temperature	Consider control later when used in emission testing

Engine rebuild conditions, engine break-in method, data recording, and instrumentation methods will all be standardized and detailed in the procedure; thus, uniform techniques in these areas will exist from laboratory to laboratory. These provisions will be established after engine selection.

With the confirmation of the engine selection, the Panel established the following procedure details:

a. A removable carburetor throttle bore sleeve will be used. Material will be aircraft aluminum (2024-7351) with a machined finish and polished surface. RMS surface finish will be in the 13 to 18 range. Initially, a single laboratory provided the sleeves.

b. Engine blowby returned to above the carburetor will be 30 cfh at engine idle (700 rpm). To obtain sufficient idle blowby, piston ring end gaps will be enlarged. Blowby will be controlled by a calibrated orifice method as provided by a laboratory.

c. Inlet air temperature will be controlled at 100° F $\pm$ 3.

d. All thermocouple locations will be established.

e. An engine break-in procedure will be established.

f. The PCV system of the engine will be made inoperable during the test.

During the latter part of 1973 and through mid-year 1974, numerous procedure changes and refinements were recommended and approved by the Panel. Draft #4 of the procedure incorporated these procedural changes. Significant changes to improve upon test repeatability and reproducibility were the following:

a. Reference oil REO 202 was developed.

b. An intake air system, which allowed for an unpressurized state in the carburetor air cleaner during the idle phase of the test cycle, was established.

c. An engine blowby temperature control system, which allowed for the return of engine blowby to the air cleaner assembly at a controlled 185° F temperature, was established. This temperature was the value at which the blowby left the rocker arm cover to enter the orifice volume control system.

d. A normal range of intake charge (air and fuel mixture) temperatures for the idle phase of the test cycle was established. This was deemed necessary to eliminate the problem of leaking EGR valves during the idle phase. Excessive intake charge temperatures had been monitored for some laboratory tests and found to be caused by leaking EGR valves (both new and used). In most cases, changing of the EGR valve corrected the excessive temperature valves.

e. In utilizing the EGR system of the engine, the system's operating vacuum was changed from the original carburetor porting to an intake manifold location. This change was necessary to insure that sufficient vacuum was available to operate the EGR valve flow at 100 percent during the cruise phase.

f. A dynamometer was determined necessary to develop deposit levels which were characteristic of field carburetors in the throttle bore area. Initially, some laboratories tested without dynamometers.

g. The engine was required to accelerate from idle to cruise phase in three to five seconds. This requirement was accomplished electrically by controlling the rate of load application by use of a resistor in the load control circuit. This method was preferred because it did not exceed the 2000 rpm limit of the cruise phase, as would be the case if the load application were delayed, as shown in Figure 1.

h. Start of test limits at the idle phase for percent CO and fuel flow were changed as follows:

	New	Old
% CO	1.3 to 1.7	Record (about 6.0 to 9.0)
Fuel Flow, lbs/hr	3.5 to 4.0	4.4 to 4.6

The new limits for idle at start of test conformed better to current manufacturer engine requirements; whereas, initial requirements gave excessively rich air-fuel ratios.

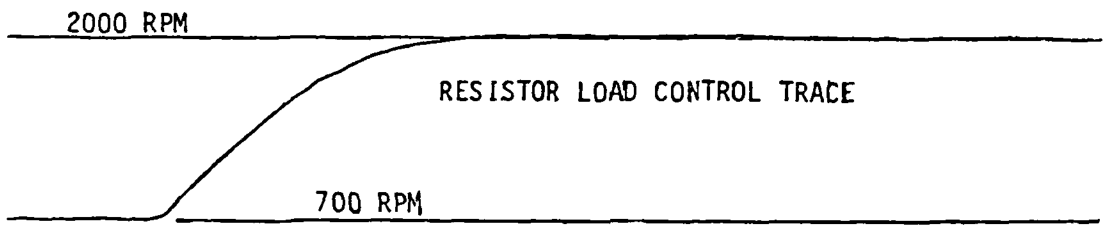
i. A sub-panel to develop and recommend a proposed method for visually rating carburetors was established.

j. Opening of the EGR valve was delayed until five seconds into the cruise phase of the test cycle. This allowed the engine to obtain the cruise phase conditions without acceleration problems due to the EGR valve operation.

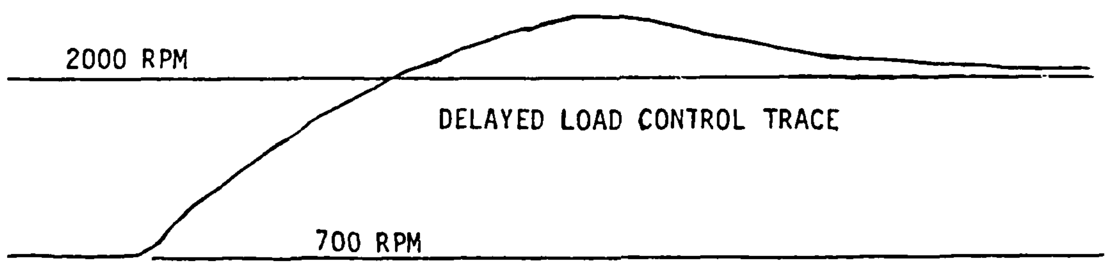
FIGURE 1

CRC CARBURETOR DETERGENCY TEST
CRUISE PHASE ACCELERATION TRACES

Electrical Control of Load:



Without Electrical Load Control:



6. Reference Oil and Fuel

a. Engine Oil

A non-detergent oil was selected as the reference engine oil. Thus, any possible contribution to carburetor cleanliness because of the engine oil was eliminated. Reference oil REO-202-73-T1 was established with the following physical description:

> "SAE 30, 95VI base oil containing only zinc dialkyl dithiophosphate and an antifoaming agent"

b. Fuel

Two reference fuels, Certified MS-08 (leaded test fuel specified for Sequence V-C engine test) and the same fuel plus 30 ppm Detergent Additive A, were used in initial test development. (Additive A was a proven carburetor detergent no longer commercially available in the US.) The fuel containing Additive A carburetor detergent provided a cleaner throttle body sleeve than the untreated fuel.

7. Initial Tests of Reference Fuels

The first reported results in mid-year 1973 utilizing the test procedure and the two reference fuels are given in Table I.

TABLE I

REFERENCE FUELS - DEPOSIT WEIGHTS

Mid-Year 1973 with Procedure Draft #2

Fuel	Laboratory:	A	C	D	E	G
MS-08		7.1	27.0	21.2	12.3	30.5
MS-08 + Additive A		1.4	6.8	17.1	4.7	6.4

It was thought that at the earliest possible time an unleaded reference fuel should be also established.

B. Test Severity Studies with Leaded Fuel

The initial test program with MS-08 gasoline indicated a need to increase test severity in order to obtain more deposits on the throttle body sleeve with and without reference carburetor detergent Additive A. Preliminary testing by several participating laboratories suggested that certain changes in the test procedure might increase severity. These modifications were further investigated by the Panel with the following results:

1. Increase Cruise Phase and Decrease Idle Phase of Test Cycle

Three laboratories investigated a longer cruise phase and concurred that increasing the time at cruise condition and decreasing the time at idle increased test severity without significantly changing the effectiveness of Additive A. Typical data are shown in Table II.

TABLE II

EFFECT OF INCREASING TIME AT CRUISE

MS-08 Fuel With and Without Additive A

Idle Cycle, min	7*	7	3	1	0
Cruise Cycle, min	1/2*	3	7	6-1/2	All
Deposit Wt, mg					
MS-08	11.7, 25.4, 10.3	46.9	107.9	69.2	87.7, 75.1 89.0,119.9
MS-08 + Additive A	3.7, 2.9	-	-	31.2	-

* Originally specified (baseline)

As a result, the test cycle was changed to 7 minutes cruise and 3 minutes idle from the initial test cycle of 1/2 minute cruise and 7 minutes idle. It was decided against a 100 percent cruise cycle, because deposit form and consistency were different than that found on the road.

2. 100 Percent EGR Operation

Full EGR flow at both idle and cruise conditions (relative to EGR during cruise only) increased carburetor deposits significantly (by a factor of about 10). The deposits were abnormally black and tarry, however, not typical of road deposits. Furthermore, there was a question concerning the effectiveness of additives under this condition. One laboratory reported that a proprietary cleanliness additive increased deposits with full-time EGR. Because of these reservations, it was decided not to incorporate EGR at idle as well as during cruise.

3. Increasing Test Length and Soak Period

Several Panel members investigated the effect of doubling the test length from 20 to 40 hours, and also looked at an 8-hour shutdown or soak period in the 20-hour test.

Generally, it was found that deposit weight doubled in 40 hours relative to 20 hours with MS-08 gasoline. The addition of an 8-hour soak period after 10 hours of operation had little or no effect on deposit level in the 20-hour test. Later, extended tests conducted by a laboratory using unleaded Phillips J gasoline generally confirmed the early MS-08 work indicating a 53 percent to 96 percent increase in deposits when test length was increased to 40 hours. There are no data showing whether the effectiveness of Additive A changed with extended test length; however, one laboratory indicated that the effectiveness of a proprietary additive did not change when test length was extended to 40 hours.

It was the consensus of the Panel not to extend test length to increase severity unless other means failed because of the increased time, cost, and the likelihood of problems when duration is extended.

4. Throttle Bore Surface Temperature

One laboratory conducted a study of the effect of throttle bore surface temperature on carburetor deposits. Results showed that throttle bore temperature under CRC test conditions (Draft #4) was higher above the throttle plate than below the throttle. The same relationship held true in a vehicle driven in traffic. In further studies using a V-8 laboratory engine, carburetor base temperature was controlled at two levels (95° F and 125° F) by substituting temperature-controlled water for exhaust gas in the passage below the carburetor. Results showed that at 95° F, throttle bore temperature was <u>higher</u> above the throttle plate than below, as experienced previously in field tests and in the CRC test procedure. At 125° F base temperature, the throttle bore temperature was <u>lower</u> above the throttle. Also observed was that carburetor deposits built up more rapidly at 95° F than at

125° F. The deposits at 95° F base temperature were more easily removed with fuel additives than those formed at 125° F. This information was presented to illustrate that surface temperature changes can have an effect on test severity, and might be a route to explore further.

5. Carburetor Sleeve Temperature Effect

One laboratory investigated the effect of changing the temperature of the removable carburetor sleeve in the CRC test. No significant change in test severity (deposit weight) was observed when sleeve temperature varied from 20° F below normal to about 80° F above normal. These observations were made with MS-08 reference fuel without Additive A.

6. Exhaust Back-Pressure Effect

No effect was observed on sleeve deposits when exhaust back-pressure was increased from the standard of 5 inches H_2O to 15 inches H_2O using both leaded MS-08 and unleaded Phillips J gasolines. The effect was not determined with Additive A present.

7. Evaluation of Commercial Leaded Gasolines

One laboratory evaluated seven commercial leaded regular grade gasolines obtained directly from service station pumps of major oil companies. Results in Table III show that in Draft #4 Test Procedure, deposit weight ranged from 0.16 mg (obtained with a low-lead fuel) to 25.0 mg.

TABLE III

CRC CLEANLINESS TEST RESULTS WITH SEVEN COMMERCIAL REGULAR-GRADE GASOLINES

Draft #4 Test Procedure
Average of Duplicate Runs

Fuel Code:	1*	2	3	4	5	6	7
Deposit Wt, mg	0.16	8.5	8.5	25.0	22.0	22.9	21.1
Deposit Rating**	9.8	5.4	7.6	4.1	6.0	5.7	5.9

* Low-lead grade
** 10 = Clean

No specific information was available as to whether or not the commercial gasolines contained carburetor detergents.

8. Effect of TEL

The effect of lead level on carburetor deposits was determined in two gasolines as shown in Table IV.

TABLE IV

EFFECT OF TEL

Average of Duplicate Runs

Phillips J			Indolene 15214		
TEL	Sleeve Deposit		TEL	Sleeve Deposit	
g/gal Pb	Wt, mg	Rating	g/gal Pb	Wt, mg	Rating
0.4	34.6	6.6	0	8.9	6.8
1.1	46.2	5.7	0.5	15.5*	5.7*
2.2	84.0	6.4	1.5	42.0	6.0*
			3.0	36.0	6.2

* Single runs

These runs show that sleeve deposit weight increases with lead content in the CRC test while visual ratings show no effect of lead content. These findings suggest a higher deposit density with leaded fuels. The data also show a difference in the carburetor cleanliness level of the two gasolines at any given lead level.

9. Intake Manifold Screen

One laboratory reported heavier carburetor deposits than other laboratories with Phillips J fuel. A suspected cause was the use of a fine wire mesh screen placed in the throat of the intake manifold which may have increased test severity. This screen was tested by two other laboratories and found to have no significant effect on sleeve deposits.

10. Performance of Detergent Additives in the Field and Laboratory

One laboratory compared the carburetor cleanup performance of four proprietary detergent additives in a twenty-car fleet test using MS-08 gasoline. The same additives were also compared for their keep-clean performance in the CRC laboratory engine tests. Results in Table V show that the CRC test separated the best and the worst carburetor detergents, but reversed the ranking of the intermediate additives.

TABLE V

PERFORMANCE OF CARBURETOR DETERGENTS IN THE FIELD AND IN THE CRC LABORATORY TEST

MS-08 Gasoline

Carburetor Detergent	CRC Test Sleeve Deposit, mg	CRC Test % Improvement	Field Test Ranking
None	115-122	-	-
A	33	73	1
B	58	53	3
C	63	45	2
D	95	17	4

This and other work reported by Panel members from time to time have shown that the CRC test generally separates carburetor detergent additives in the same manner as in vehicle tests when tested in leaded fuel. There was general agreement that the test procedure was acceptable when using leaded fuel. At this period in the test development, there were limited data (primarily with Phillips J) indicating the CRC test gave considerably less deposit weight with unleaded gasolines; thus, there could be difficulty in obtaining significant separation among different fuel performance levels.

C. Test Severity Studies with Unleaded Fuel

1. Individual Laboratory Exploratory Studies

At the June 1976 Panel meeting, it was decided to investigate the effect of several test procedure modifications on unleaded fuel test severity. Each participating laboratory was given a particular modification to study in its test engine using Phillips J fuel. The results of eight modifications studied are as follows:

a. Test Cycle Variation - Reducing the idle phase time relative to time at cruise condition increased carburetor deposits. Continuous cruise (without idle) was most effective in increasing deposits. A similar relationship was found in earlier studies with MS-08 leaded gasoline.

b. Intake Air Temperature - Increasing inlet air temperature increased deposits.

c. Blowby Flow Rate - Increasing blowby gas flow rate had no effect on deposits.

d. Extended Test Length - Increasing test length from 20 to 40 hours increased deposits.

e. Continuous EGR Flow Rate - Continuous EGR flow rate during idle as well as during the cruise phase had no significant effect on deposit level.

f. Used Oil Effect - Using the same oil for more than one test can either increase carburetor deposits or have no effect. With the regular oil for this test (REO-202), aged oil increased deposits. With a fully formulated oil (REO-209) containing 1 percent sulfated ash, however, the effect of aged oil on deposits was negligible. Additive A was still effective in the used oil.

g. Air-Fuel Ratio Change - Operation at a leaner idle condition (0.1 percent CO versus 1.5 percent CO) had no significant effect on deposits.

h. High Throttle Body Temperature - Increasing sleeve temperature increased deposits. Effect on the response of Additive A was not determined.

2. Studies of Test Cycle Change Combined with High Inlet Temperature

As the result of the above investigations, it was decided to study further variations in the test cycle in combination with higher intake air temperature. Additional testing by six laboratories generally confirmed that continuous cruise operation (no idle) or a cycle with a minimum of idle (9/1 cruise/idle) increased deposits relative to the current 7/3 cruise/idle cycle when tested in conjunction with high intake air temperature (up to 200° F). The degree of effectiveness of Additive A varied considerably among the laboratories using these modifications; therefore, the question of additive response was not resolved.

3. Carburetor Effects

Poor reproducibility (among laboratories) has always been a problem with the CRC test, even though repeatability (within a given laboratory) has been acceptable. One laboratory ran a series of tests on the same engine using two separate carburetors and found deposit weight of 25-30 mg with one (in-house modified carburetor) and 7-10 mg with the other (Carter modified carburetor), suggesting that poor reproducibility among laboratories may be due to the difference in individual carburetors. The Carter modified carburetor was passed around to several laboratories for testing to see if a common carburetor would improve reproducibility. Results of this round-robin test are reported in the section on Test Programs and showed no significant change in reproducibility.

4. Engine Load Effects

Some laboratories had been operating at lower loads under cruise conditions than specified by the test procedure. A study by one laboratory of the effect of varying cruise load indicated that as engine load increased, deposits tended to decrease.

5. Carburetor Heat Shield/Flange Gasket Effect

The same laboratory determined that operating without a heat shield below the carburetor increased carburetor deposits slightly.

6. Idle Fuel Flow

Further studies to determine ways to increase deposit level with unleaded fuel involved investigating the effect of increased idle fuel flow. In a four-laboratory study, three showed no effect on deposits when the fuel flow was increased from 3.75 to 4.75 lb/hr, and one laboratory showed a small increase in deposits (from 10.1-13.7 mg to 14.2-18.2 mg).

7. Increase in Cruise Speed

Three laboratories investigated the effect of increasing cruise speed from 2000 rpm to 2200 rpm, and all showed no effect on carburetor deposit level.

D. Equipment and Procedure Development

During development of the procedure, many equipment and procedure clarifications were made by the Panel. The following items were agreed upon by Panel members. These items were found to influence both test repeatability and reproducibility, demonstrating the need for cooperative agreement.

1. Engine Overhauls and Pre-Test Conditioning

The engine is rebuilt when idle blowby is above the desired natural level of 40 to 60 cfh or for obvious mechanical reasons. Rebuild consists of removing all deposits and replacing all parts necessary to restore clearances and tolerances specified by the engine manufacturer. The only modification to the engine is done after engine break-in and is an increase in piston ring gaps to obtain the desired range of idle natural blowby. Usually, ring gaps of about 0.050 inch are required.

After engine overhaul and break-in and before return to fuel testing, the engine needs to be pre-conditioned on some known reference fuel to build up stabilized combustion chamber deposits. Several twenty-hour tests are usually required to stabilize base fuel combustion chamber deposit levels in the engine. Normally, carburetor deposit levels will initially be low and then increase to expected levels.

Summary data on cylinder head overhauls and major engine overhauls at the June 1979 meeting revealed that average cylinder head overhauls were completed after 56+ test runs, and average major engine overhauls were completed after 213+ test runs.

2. Fuel System Flushing

To prevent possible fuel/additive carryover effects from the previous tests, the fuel sytem lines must be flushed for two hours with the next base fuel to be tested. Additive carryover effects are normally present when tests are run directly after an additive-treated fuel without a flush. Usually, two or more base fuel runs may be required to stabilize deposit levels. The use of a fuel system flushing procedure will eliminate the need to complete the stabilizing base fuel runs. The additive carryover effect and the effective use of a fuel system flushing are demonstrated in Table VI.

TABLE VI

ADDITIVE CARRYOVER EFFECT

Carburetor Sleeve

Fuel	Deposit, mg	Remarks
Base Fuel	26.3	Consecutive Runs
Base Fuel	32.0	
Base Fuel	28.0	
Base Fuel + Additive	3.2	
Base Fuel	15.2	Carryover Effect
Base Fuel	26.9	
Base Fuel + Additive	8.2	Use of flush after run
Base Fuel	31.7	No Carryover Effect
Base Fuel + Additive	9.3	Use of flush after run
Base Fuel	30.6	No Carryover Effect

3. Base Fuel Substitution Carryover Effects

After completion of a fourteen-run test program by the Panel utilizing Draft #4, Supplement Addition (dated March 10, 1975) of the procedure, the results indicated a carryover effect when a different baseline fuel is substituted for the previous fuel. This carryover effect is most prominent when changing from leaded to unleaded fuel and vice versa. Thus, extreme caution needs to be maintained to insure that base fuel and additive carryover effects are controlled in testing.

4. Carburetor Base Gaskets

Studies by the Panel members indicated that a deposit level effect can be experienced when carburetor gaskets of different thickness are used between the carburetor base and the heat shield. This effect is demonstrated in Table VII.

TABLE VII

CARBURETOR BASE GASKET EFFECT

Phillips J Fuel

Laboratory	Gasket Thickness, in	Deposit Wt, mg
B	0.09	15.1
	0.011	28.6
C	0.09	11.1*
	0.03	16.3**

* Average of seven runs.
** Average of two runs.

5. Carburetor and Sleeve Supplier

Specified in Draft #6 of the procedure dated March 1, 1978, was a supply source of modified carburetors for testing. It was thought that this type of supplier would help to eliminate differences in throttle bore and sleeve modifications which affect testing. It was recommended that laboratories begin using carburetors from the supplier.

6. Test Engine Replacement - Ford 300-CID

The procedure is written for use with either a 240-CID or 300-CID Ford six-cylinder engine. The latter engine was added because the 240-CID engine is no longer available. The following items were deemed necessary and important in using the 300-CID engine for testing. All items are detailed in Draft #6 dated March 1, 1978.

a. A single standard carburetor is to be used for both the 240 and 300 engines.

b. The thermactor air pump system and lines must be removed from the 300 engine.

c. The external EGR system of the 300 engine must be modified.

d. The electronic ignition for the 300 engine is used as received. Consequently, the 240 engine ignition has been converted to electronic in the procedure.

In comparing test results between the two engines, the 300 generally gives higher deposit levels, but response to Additive A has been similar to the 240 engine.

7. Chronological Test Procedure Development

During development of the procedure, numerous written drafts of the procedure were completed. A listing and description of highlights and testing for each procedure draft follows.

a. Draft #1 - Dated May 22, 1972

This procedure was the initial attempt to establish guidelines for a carburetor cleanliness test before a test engine was selected. Limited testing with the procedure was completed after engine selection. From this testing, many requirements and clarifications were determined for the test procedure and were incorporated into the next subsequent draft.

b. Draft #2 - Dated June 22, 1973

The following main test items were established in the procedure:

-- use of an engine load during the cruise phase;

-- specification of fuel flow rates for idle and cruise phases;

-- specification of thermocouple locations;

-- requirement of humidified air for test;

-- use of reference oil REO 202 for test;

-- use of a removable throttle bore sleeve;

-- requirement of a fixed orifice return blowby control system;

-- specification of exhaust back-pressure for cruise;

-- specification of engine break-in conditions;

-- specification of rebuild methods;

-- acceleration time requirement of engine to cruise phase;

-- specification of two leaded reference fuels (MS-08 and MS-08 plus Additive A).

Using this draft, more than fifty test runs were reported by Panel members, mostly with leaded fuels. These results indicated that the procedure required more definition and refinement in several areas to improve repeatability and reproducibility; thus, Draft #3 evolved.

c. Draft #3 - Dated July 24, 1973

Major changes and clarifications to the procedure were the following:

-- specification that the maximum oil sump temperature be 220° F;

-- specification that the maximum fuel pressure be 5 psi;

-- instructions for obtaining emission data;

-- improved procedure for weighing throttle bore sleeve;

-- improved details specifying a blowby return control system;

-- information to obtain flow-checked EGR valves;

-- better clarification as to engine vacuum hose connections.

Twenty-four tests were reported using this draft. Panel evaluation of these tests resulted in the reduction of fuel flow and percent CO level at the idle phase condition to eliminate excessively rich air-fuel ratios.

d. Draft #4 - Dated March 19, 1974

This draft incorporated the following major items:

-- specification of 1.3 to 1.7 percent CO level at idle phase at test startup;

-- specification of 3.5 to 4.0 lbs/hr fuel flow at idle phase at test startup;

-- delay of EGR operation until five seconds into the cruise phase;

-- acceleration to 2000 rpm cruise phase condition from 0:03 - 0:05 minute at start of phase;

-- control of engine blowby gas return temperature at 185° F;

-- connection of spark advance retard line as specified by the manufacturer.

Over one hundred sixty tests were reported using this procedure. One hundred of the tests were involved with test severity studies to evaluate leaded and unleaded fuels. Of major consequence from these studies was the need to increase the test deposit level with unleaded fuels. As a result of this testing, the Panel made a major change in the procedure cycle times to increase unleaded fuel deposit levels. A supplement for this draft was written for the cycle time changes and several other changes.

e. Draft #4, Supplement Addition - Dated March 10, 1975

The supplements to the procedure were the following:

-- change of test cycle times to: idle phase of 3.0 minutes and cruise phase of 7.0 minutes;

-- requirement of fuel line flushing between tests;

-- specification of actual required test times to measure idle and cruise phase temperatures;

-- consideration of partial blockage for the transfer port in the carburetor throttle base;

-- specification of visual ratings for throttle bore sleeve after test;

-- use of Phillips J fuel as an unleaded reference fuel.

Extensive testing was completed with this draft. Over three hundred tests were reported by Panel members. The fourteen-test severity program was completed at this time. Sixty percent of the tests reported utilized unleaded fuel, and many were involved with severity studies.

f. Draft #5 - Dated April 29, 1977

As a result of the test severity studies in 1976, changes were made prior to conducting the ten-test program.

-- increase of intake air temperature to 150° F;

-- specification that heat-rise valve be locked in open position.

g. Draft #6 - Dated March 1, 1978

This draft was initially distributed to the Panel members in September 1977 for their corrections and comments, which were incorporated into this draft before being reissued. This draft was a complete rewrite of the procedure, and major changes and additions were:

-- written for use with either the Ford 1973 240-CID or 1977 300-CID engines;

-- description of cleaning method for the upper area of the carburetor;

-- information to obtain modified test carburetors and throttle bore sleeves from a supplier;

-- inclusion of the proposed CRC Carburetor Rating Method as an appendix;

-- correction of EGR valve part numbers;

-- redrawing and updating of all attachments;

-- incorporation of a new data summary sheet.

One hundred seventy tests were reported utilizing this procedure draft. The ten-test and six-test programs were completed during this time, along with the Carburetor Round-Robin Program. Again, numerous unleaded fuel severity studies were made.

h. Draft #6 - Dated March 1, 1978 (Modified for Unleaded Fuel Correlation Program - Dated August 1, 1980)

Because of the many modifications investigated with Draft #6 prior to the Unleaded Fuel Correlation Program, the procedure was reissued to insure that the participating laboratories would utilize the same draft for the program. The only major change in the procedure was to establish basic spark timing conditions for the 240-CID and 300-CID engines.

Fifty-four tests were reported to the Panel for this program. Extensive data analysis of results was completed.

i. Current Test Procedure

Appendix B contains the current or final test procedure as balloted and approved by the Panel.

E. Test Programs

Several test programs involving six or more fuel tests were conducted by the Panel to investigate various aspects of the test procedure during the course of development. These are summarized below:

1. Fourteen-Test Severity Program

In February 1975, the Panel decided that each laboratory should run a fourteen-fuel test program using the test procedure designated as Draft #4, Supplement Addition (dated March 10, 1975). The purpose was to investigate the effect of specific changes in the test procedure on test severity. Also studied were test variability (repeatability and reproducibility) and the ability to discriminate among various fuels including leaded versus unleaded.

The test procedure changes evaluated in this program were:

-- test cycle consisting of 3 minutes idle and 7 minutes cruise;

-- changes in fuel rate and CO to:

3.75 ± 0.25 lb/hr fuel rate at idle
9.5 ± 0.1 lb/hr fuel rate at cruise
1.5 ± 0.2 percent CO at idle

-- change in time for acceleration rate and for start and end of full EGR flow;

-- use of new preselected EGR valve;

-- partial engine rebuild before start of program;

-- fuel line flush procedure for elimination of carryover of preceding fuel.

The testing sequence consisted of running duplicate tests on each of the following fuels in the order shown for a total of fourteen runs:

1. Phillips J
2. Indolene 15214
3. MS-08
4. Phillips J + Additive A
5. Indolene 15214 + Additive A
6. MS-08 + Additive A
7. Phillips J

(Repeat 1 through 7)

Four laboratories completed the program. Deposit weights are summarized in Table VIII.

TABLE VIII

SUMMARY OF DEPOSIT WEIGHTS AND ANALYSIS OF VARIANCE

Fourteen-Test Severity Program - Draft #4, Supplement Addition

Fuel	Lab:	Sleeve Deposit Weights, mg B	C	J	F
Phillips J		11.6	10.4	15.2	7.4*
Phillips J		12.4	18.2	21.7	6.4
Indolene 15214		12.1	4.6	9.6	11.2
Indolene 15214		10.6	9.1	5.7	6.7
MS-08		95.7	80.3	95.8	96.0
MS-08		90.0	139.2	124.0	138.2
Phillips J + Additive A		1.1	1.3	0.5	2.9
Phillips J + Additive A		0.8	0.9	2.1	1.0
Indolene 15214 + Additive A		0.4	2.3	5.6	2.3
Indolene 15214 + Additive A		3.8	3.5*	4.3	2.4
MS-08 + Additive A		39.9	14.0	30.0	58.6
MS-08 + Additive A		34.1	16.4	21.3	63.6
Phillips J		22.0	17.5*	23.4	7.0
Phillips J		13.2	26.8	21.5	7.8

Analysis of Variance Results @ 90% Confidence Level

Source	SSD	df	(Standard Deviation)^2	F Ratio	F Table	Significant
Fuels	68,981.6	13	5306.3	45.4	1.68	Yes
Labs	212.8	3	70.9	0.61	2.23	No
Error	4,559.82	39	116.9			
Total	73,754.22	55				

* Estimated value for ANOVA.

Table IX summarizes the effect of the different fuels on deposit weights across five laboratories (one which reported data only for Phillips J). Table X shows the corresponding weights and visual deposit ratings for Phillips J from five laboratories.

TABLE IX

CRC CARBURETOR CLEANLINESS TEST

Fourteen-Test Severity Program

Fuel	No. of Tests	Average Sleeve Dep. Weight, mg	Standard Deviation, mg	Coefficient of Variation, %
Phillips J	17	14.5	4.7	33
Indolene 15214	8	8.7	2.7	31
MS-08*	8	107.4	27.6	26
Phillips J + Additive A	8	1.3	0.9	68
Indolene 15214 + Additive A	7	2.9	1.5	52
MS-08* + Additive A	8	34.7	4.2	12

* Leaded; all others unleaded.

TABLE X

SLEEVE DEPOSIT WEIGHTS VERSUS VISUAL RATINGS

Fourteen-Test Severity Program - Draft #4, Supplement Addition

Phillips J Fuel

Laboratory		Deposit Weight, mg	Carburetor Visual Rating*	Correlation Coefficient
B		11.6	5.9	
		12.4	5.8	
		22.0	4.3	
		13.2	4.5	0.74
	Mean	14.8	5.1	
	SD/CV	4.8/32%	0.8/16%	
C		10.4	3.7	
		18.2	2.9	
		26.8	3.8	0.13
	Mean	18.5	3.5	
	SD/CV	8.2/44%	0.5/14%	
E		12.9	6.2	
		10.6	5.7	1.00
	Mean	11.8	6.0	
	SD/CV	1.6/14%	0.4/6%	
J		15.2	6.2	
		21.7	6.2	
		23.7	6.9	
		21.5	6.7	0.69
	Mean	20.5	6.5	
	SD/CV	3.7/18%	0.35/6%	
F		6.4	7.0	
		7.0	7.0	
		7.8	6.6	0.90
	Mean	7.1	6.9	
	SD/CV	0.7/9.8%	0.2/3%	
	Overall Mean	14.5	5.6	
	Overall SD/CV	4.8/33%	0.5/10%	
	Overall CV			0.31

* 10 = Clean

The fourteen-test severity program showed:

- Significant cleanliness differences among the fuels with MS-08 leaded fuel giving the most deposits and Phillips J and Indolene unleaded fuels giving the least. Among the unleaded fuels, Phillips J gave heavier deposits than Indolene.

- Additive A was effective in reducing deposits in all three gasolines, but was most effective in Phillips J (91 percent reduction versus 66 percent and 68 percent in other fuels).

- Overall variability was high in terms of both repeatability and reproducibility.

- Analysis of variance indicated that laboratories are not significantly different in their ranking of the various fuels.

- Variability was greater with fuels containing Additive A than with the base fuels alone.

- There appeared to be a carryover from the preceding fuel when switching from leaded to unleaded fuel (or vice versa) or from detergent to non-detergent fuel (or vice versa). The data suggest that at least two tests should be run on the next fuel to eliminate carryover completely.

- There does not appear to be a significant variation in deposit weight associated with normal variations of the following operating conditions:

fuel flow	total fuel consumption
intake manifold vacuum	bhp at cruise
oil temperature at idle	intake charge temperature
air/blowby mixture temperature	

- Overall, there is a poor correlation (0.31 coefficient of correlation) between sleeve deposit weights and visual deposit ratings. Because of this finding, additional work was undertaken to develop further a rating scale, including two rating workshops.

2. Ten-Test Program

In March 1978, Draft #6 of the test procedure was prepared which included the following major changes:

-- Inclusion of 1977 Ford 300-CID engine as an alternate test engine.

-- Use of a modified, bench-flowed carburetor from a single supplier.

-- Procedure for cleaning the upper part of the carburetor prior to each test.

-- Addition of the CRC Carburetor Deposit Rating Method.

-- Designation of the proper EGR valve part number.

In order to validate this new draft of the procedure, laboratories were requested to conduct a ten-test program with the following fuels run in duplicate in the order shown:

Phillips J
Phillips J + Additive A
Phillips J
MS-08
MS-08 + Additive A

Deposit weights from the three laboratories that reported data are shown in Table XI.

TABLE XI

DEPOSIT WEIGHTS FROM TEN-TEST PROGRAM

Draft #6 Test Procedure

Order of Testing Fuels	Lab: B	E	H	Mean	Standard Deviation
	Sleeve Deposit Weights, mg				
Phillips J	11.9	12.2	16	13.4	2.4
Phillips J	19.1	13.8	11	14.6	4.1
Phillips J + Additive A	1.0	3.5	1	1.8	1.4
Phillips J + Additive A	0.4	3.4	1	1.6	1.6
Phillips J	13.9	10.0	23	15.6	6.7
Phillips J	11.8	13.7	12	12.5	1.0
MS-08	78.8	88.5	106	91.1	13.8
MS-08	85.2	99.4	93	92.5	7.1
MS-08 + Additive A	6.9	43.6	22	24.2	18.4
MS-08 + Additive A	6.8	39.1	10	18.6	17.8

The data showed that:

- The laboratories ranked the four fuels in the same order.

- Repeatability within laboratories was acceptable. Reproducibility among laboratories was not as good as repeatability. This was also shown in the fourteen-test program.

- Unleaded Phillips J deposit levels were still low and the effectiveness of Additive A was still greater than desired in this fuel.

- Deposit levels with leaded MS-08 fuel with and without Additive A were deemed satisfactory.

It was concluded that additional effort was needed to increase the deposit levels with Phillips J and Phillips J + Additive A.

3. Six-Test Program

Independent work by various laboratories indicated that heavier deposits with Phillips J and with Phillips J containing Additive A could be obtained with a thinner carburetor gasket between the carburetor base and heat deflector shield and with a higher volume of EGR flow. A six-test program was initiated, and participating laboratories were requested to use the Draft #6 procedure with the following specific hardware:

-- Thin carburetor gasket from Ford tune-up kit CT-842A (DODZ-9A586-B).

-- Larger EGR flow valve, Ford Part No. D4DE-9D475-E2A for 240-CID engine.

Deposit weights from the four laboratories that completed the tests are shown in Table XII.

TABLE XII

DEPOSIT WEIGHTS FROM SIX-TEST PROGRAM

Draft #6 Procedure with Thin Carburetor Gasket
and Larger EGR Valve

Order of Testing Fuels	Lab:	Sleeve Deposit Weights, mg					
		C*	E	H	K**	Mean	Standard Deviation
Phillips J		10.9	57.9	15	40.9	31.2	22.2
Phillips J		13.2	41.0	16	35.2	26.3	13.8
Phillips J + Additive A		0.1	6.1	1	5.9	3.3	3.2
Phillips J + Additive A		2.6	1.0	1	3.9	2.1	1.4
Phillips J		10.8	10.6	12	31.6	16.2	10.2
Phillips J		10.9	23.8	12	33.1	20.0	10.5

* Used old carburetor; all others used Carter modified.
** Laboratory K used 300-CID engine.

Results show that the use of the thin gasket and larger EGR valve did not increase test severity (except for Laboratory E) or change the response of Additive A. This can be determined by comparing the six-test results with the previous ten-test results. Laboratory K, using the 300-CID engine, showed greater test severity than laboratories using the 240-CID engine, but Additive A response was still very high. Again, repeatability was acceptable, but reproducibility was poor.

4. Carburetor Round Robin

After completion of the six-test program (Section V.E.3), a carburetor round-robin program was conducted. Results of the six-test program indicated a need for more investigation to improve procedure reproducibility. Even with the use of carburetors which were modified, flow-checked, and purchased from the same supplier, reproducibility was not as good as desired.

Independent work by one laboratory indicated the dramatic effect of the carburetor on deposit levels. The test work was completed on the same engine with two carburetors: one as modified by the supplier, and the other as modified by the laboratory. The results are shown in Table XIII.

TABLE XIII

EFFECT OF CARBURETOR MODIFIER

Draft #6 Procedure with Thin Carburetor Gasket
and Larger EGR Valve

Test No.	Carburetor Information	Deposit Wt, mg Phillips J Base
1	Supplier-Modified	8.7
2	Supplier-Modified	7.6
3	Supplier-Modified	8.7
4	Laboratory-Modified	27.0
5	Supplier Upper Body with Laboratory Throttle Body (Base and Sleeve)	17.7
6	Laboratory Upper Body with Supplier Throttle Body (Base and SLeeve)	22.4
7	Supplier-Modified	9.5

Results indicated that the two carburetors produce radically different results when operated on the same test stand. The laboratory in-house modified carburetor produced deposit weights with the Phillips J fuel in the range of 25 to 30 mg. Yet, the supplier-modified carburetor produced lower deposit weights (7 to 10 mg). Noteworthy also was the effect of interchanging the carburetor sections.

Because of the carburetor effects, several laboratories were requested to complete the round-robin program utilizing the supplier-modified carburetor from Table XIII. Each laboratory was asked to make several runs with the round-robin carburetor and Phillips J base fuel. Each laboratory established a deposit level for their engine before sending the carburetor to the next laboratory. No major adjustments were made to the carburetor between the laboratories. Results of the round-robin program are given in Table XIV.

TABLE XIV

CARBURETOR ROUND-ROBIN PROGRAM

Draft #6 Procedure with Thin Carburetor Gasket
and Larger EGR Valve

Phillips J Base Fuel

Laboratory and Round-Robin Order	Deposit Weight, mg Run 1	Run 2
H	16	19
D	9.6	8.6
C	10.0	5.0
E	26.3	20.7

Results of the round-robin program also gave unsatisfactory reproducibility results. This indicated that other engine and procedure variables were superseding the carburetor effect. The use of different Phillips J fuel batches probably affected the reproducibility.

A computer statistical analysis of the round-robin program and other current testing was completed by the Panel at this time. Results of this analysis were the following:

Correlation of Variables with Deposits

Several variables were significantly related to variations in sleeve deposit weight:

- The round-robin carburetor gave deposits 60 percent lower than individual laboratory carburetors.
- Start of test hydrocarbon emissions at idle increased deposit weight about 1 percent for each increase of 10 ppm.
- Manifold vacuum at idle increased deposit weight about 14 percent per inch of increased vacuum.
- Blowby at idle increased deposit weight almost 2 percent per cfh.

- Temperature of blowby-air mixture at idle increased deposit weight almost 3 percent per degree.

- Temperature of oil gallery at idle decreased deposit weight about 2 percent per degree Fahrenheit increase.

- The difference between idle and cruise intake charge temperature increased deposit weight about 3 percent per 10 degrees difference.

- The difference between idle and cruise blowby temperatures decreased deposit weight about 6.5 percent per degree difference.

- Oil pressure at idle increased deposit weight about 2 percent per psi.

- Fuel pressure at idle decreased deposit weight about 3 percent per 0.1 psi.

These effects account for all the significant differences among laboratories. Keep in mind that the effects as found (all of those mentioned are significant at the 90 percent level or higher) did not necessarily reflect "cause and effect." All that can be logically concluded is that significant variations in deposit weight are associated with higher or lower values of the various test variables. Residual error is still almost 40 percent after accounting (adjusting) for these effects.

Many laboratories consistently did not report one or more of the many variables; hence, some variable effects could not be estimated. The variables which could not be studied were:

- blowby at cruise phase;

- exhaust back-pressure at cruise phase;

- humidity;

- total test fuel weight;

- start of test cruise phase CO emissions;

- start of test cruise phase HC emissions;

- blowby air mixture temperature at cruise phase.

5. Unleaded Fuel Correlation Program

With the completion of the round-robin program, the Panel decided to complete a fuel correlation program. Six fuels were selected for the program. All fuels were unleaded and no detergent-type fuel additives were present. The fuels were labeled and given the following general descriptions, as determined before actual testing. Complete fuel inspections are summarized in Table XV, and detailed fuel compositions are found in Appendix D for each fuel.

Fuel Label	General Fuel Type
CRC-CTF-1	Phillips J (Batch 10)
CRC-CTF-2	90 percent Phillips J (Batch 10) + 10 percent Ethanol
CRC-CTF-3	Clean Fuel
CRC-CTF-4	Dirty Fuel
CRC-CTF-5	Average Fuel
CRC-CTF-6	Moderately Dirty Fuel

Nine laboratories participated in the program. The intent of the program was to determine if laboratories would rank these fuels in the same order.

Laboratories were requested to run the fuels in the following random sequence order. Two laboratories utilized the 300-CID engine.

1)	CRC-CTF-6	7)	CRC-CTF-4
2)	CRC-CTF-3	8)	CRC-CTF-2
3)	CRC-CTF-5	9)	CRC-CTF-1
4)	CRC-CTF-1	10)	CRC-CTF-6
5)	CRC-CTF-5	11)	CRC-CTF-2
6)	CRC-CTF-3	12)	CRC-CTF-4

Laboratories were asked to complete the program without interruption in the test sequence order. To insure that all laboratories would run the tests the same way, procedures were issued to all participating laboratories for this program.

TABLE XV

FUEL INSPECTIONS
CRC CARBURETOR TEST PROCEDURE PANEL FUEL CORRELATION PROGRAM

Inspection	CRC CTF-1	CRC CTF-2	CRC CTF-3	CRC CTF-4	CRC CTF-5	CRC CTF-6
Gravity, °API	54.0	52.7	67.5	52.7	58.8	59.5
Reid Vapor Pressure, lb	10.0	10.8	7.9	8.2	10.5	10.4
D 86 Distillation, °F						
Initial Boiling Point	95	99	83	90	99	88
10% Evaporated	112	115	135	133	123	122
30% Evaporated	162	144	171	175	175	166
50% Evaporated	234	215	209	229	226	207
70% Evaporated	261	254	241	300	275	260
90% Evaporated	326	318	308	390	346	350
End Point	400	394	372	442	422	435
Sulfur, wt %	0.010	0.008	<0.001	0.10	0.015	0.11
Nitrogen, ppm						
Total	18	17	6	268	16	30
Basic	13	10	5	232	13	22
Hydrocarbon Type, FIA vol %						
Aromatics	45	48	7	37	28	24
Olefins	7	7	0	18	10	7
Saturates	48	45	93	45	62	69
Alcohol Content, vol %	-	10	-	-	-	-
ASTM Gum, mg/100 ml						
Unwashed	2	3	1	5	3	7
Washed	0	1	0	4	2	0
Induction Period, hr	24+	24+	24+	24+	24+	24+
Lead Content, g/gal	<0.003	<0.002	<0.003	<0.002	<0.002	<0.003
Research ON	95.1	97.7	88.7	92.0	91.4	90.0
Motor ON	84.9	86.3	85.4	81.1	83.6	81.8

Table XVI summarizes deposit weights and visual ratings. The Panel concluded the following from the results in Table XVI:

- Reproducibility of deposit weights was poor among the laboratories, as found in similar test programs.
- Rank of fuels, by deposit weights, among the laboratories was considered acceptable. Table XVII summarizes fuel rankings according to deposit weights. Fuels 3 and 5 produced the least deposits and were ranked either first or second by six of the nine laboratories. It was thought that Fuel 6 would produce higher deposits due to its higher sulfur level, but this was not observed. Fuel 6 ranked third overall; but in three laboratories, Fuel 6 was ranked second with Fuel 3 being ranked third. All laboratories ranked Fuel 2, the gasohol, in sixth or last place with the highest deposit level.
- Table XVIII summarizes the fuel rankings according to visual ratings. The weight and visual rankings correlate well within the laboratories. The correlation rankings of deposit and visual rankings were the same.
- Laboratories H and K with 300-CID engines had good correlation in deposit levels.
- Good correlation was also noted with Laboratories B, H, and K, which utilized "Go Power" dynamometers.
- It was thought that minimal carryover effect from different base fuels was present even though a singular random test order was used.

Results of this program were submitted to complete analysis of deposit levels, visual ratings and operating conditions. The conclusions of this analysis were as follows:

a. <u>Complete Data</u>

Figures 2 and 3 show the correlation among laboratories for deposit weight (Figure 2) and for visual rating (Figure 3) when compared with the corresponding grand average as given in Table XVI. For a good correlation, the slopes of the various laboratories should be parallel to each other. As observed, these slopes are different.

TABLE XVI

DEPOSIT WEIGHTS AND VISUAL RATINGS
CRC CARBURETOR TEST PROCEDURE PANEL FUEL CORRELATION PROGRAM

Fuel \ Laboratory	A	B	C	D	E	G	H	I	K	Grand Average
Deposit Weights										
CTF-1	16.3/18.9	26.0/28.9	39.4/34.1	28.6/25.0	29.3/21.3	40.5/39.6	27.2/31.3	28.0/31.0	32.3/33.1	29.49
CTF-2	56.5/53.0	67.6/61.9	74.1/79.1	44.3/33.7	85.6	73.5/47.4	89.9/88.3	90.0/65.0	84.9/75.7	69.78
CTF-3	2.2/3.6	5.8/ 5.4	8.9/ 9.6	14.2/10.0	7.9/ 4.8	16.6/ 9.8	7.0/ 7.2	10.0/15.0	11.1/ 7.2	8.68
CTF-4	36.8/33.0	36.8/25.1	41.0/58.5	35.0/21.8	26.1/17.5	31.8/12.0	59.2/76.9	17.0/13/0	55.2/66.8	36.86
CTF-5	2.7/ 3.7	4.6/ 3.7	8.9/ 5.1	4.0/ 8.9	9.9/ 7.7	6.0/ 5.4	10.1/11.5	3.0/ 1.0	8.4/12.9	6.53
CTF-6	10.0/14.3	13.5/14.6	17.6/12.4	12.0/11.6	21.0/13.4	13.1/ 9.6	18.5/20.4	11.0/ 9.0	24.9/23.0	14.99
Visual Ratings										
CTF-1	5.9/6.0	6.1/5.9	6.1/6.1	4.9/5.4	6.0/5.4	5.4/5.7	-	5.3/5.8	5.4/5.3	5.67
CTF-2	3.9/4.3	3.7/3.8	3.5/4.6	4.7/4.5	1.6	3.5/5.1	-	2.9/2.6	3.2/2.2	3.48
CTF-3	7.3/7.4	6.6/7.1	8.2/6.9	6.3/6.3	7.7/7.2	7.6/7.4	-	6.5/7.0	5.8/6.0	6.96
CTF-4	5.4/5.4	5.7/5.8	6.3/6.5	4.9/4.7	4.6/6.7	6.1/7.3	-	5.9/6.8	5.3/4.8	5.76
CTF-5	7.4/7.1	7.3/7.3	7.8/7.9	6.9/7.2	6.5/6.8	7.6/8.1	-	7.8/8.7	6.6/7.0	7.37
CTF-6	6.3/6.1	6.4/6.1	7.0/7.8	6.2/5.9	6.7/6.8	6.4/7.3	-	6.5/6.7	5.3/5.5	6.44

TABLE XVII

FUEL RANKING BY DEPOSIT WEIGHT
CRC CARBURETOR TEST PROCEDURE PANEL FUEL CORRELATION PROGRAM

Fuel \ Laboratory	A	B	C	D	E	G	H	I	K	Average Ranking
CTF-1	4	4	4	4	5	5	4	5	4	4
CTF-2	6	6	6	6	6	6	6	6	6	6
CTF-3	1	2	2	3	1	3	1	3	1	2
CTF-4	5	5	5	5	4	4	5	4	5	5
CTF-5	2	1	1	1	2	1	2	1	2	1
CTF-6	3	3	3	2	3	2	3	2	3	3

TABLE XVIII

FUEL RANKING BY VISUAL RATING
CRC CARBURETOR TEST PROCEDURE PANEL FUEL CORRELATION PROGRAM

Fuel \ Laboratory	A	B	C	D	E	G	H	I	K	Average Ranking
CTF-1	4	4	5	4	4	5	No Ratings	5	4	4
CTF-2	6	6	6	6	6	6		6	6	6
CTF-3	1	2	2	2	1	2		2	2	2
CTF-4	5	5	4	5	5	4		4	5	5
CTF-5	2	1	1	1	3	1		1	1	1
CTF-6	3	3	3	3	2	3		3	3	3

FIGURE 2

LN DEPOSIT WEIGHT

Laboratory Averages Versus Grand Averages

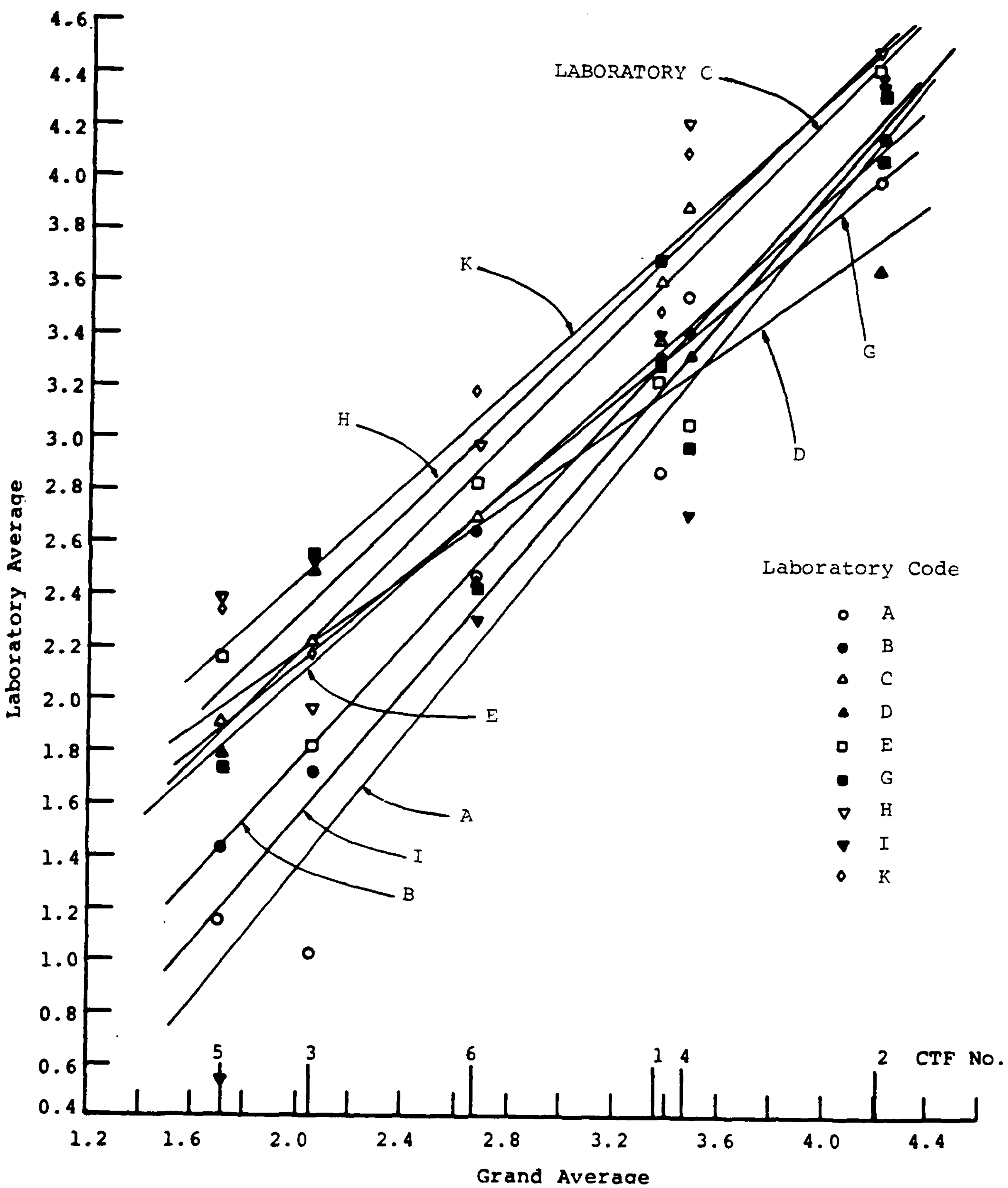
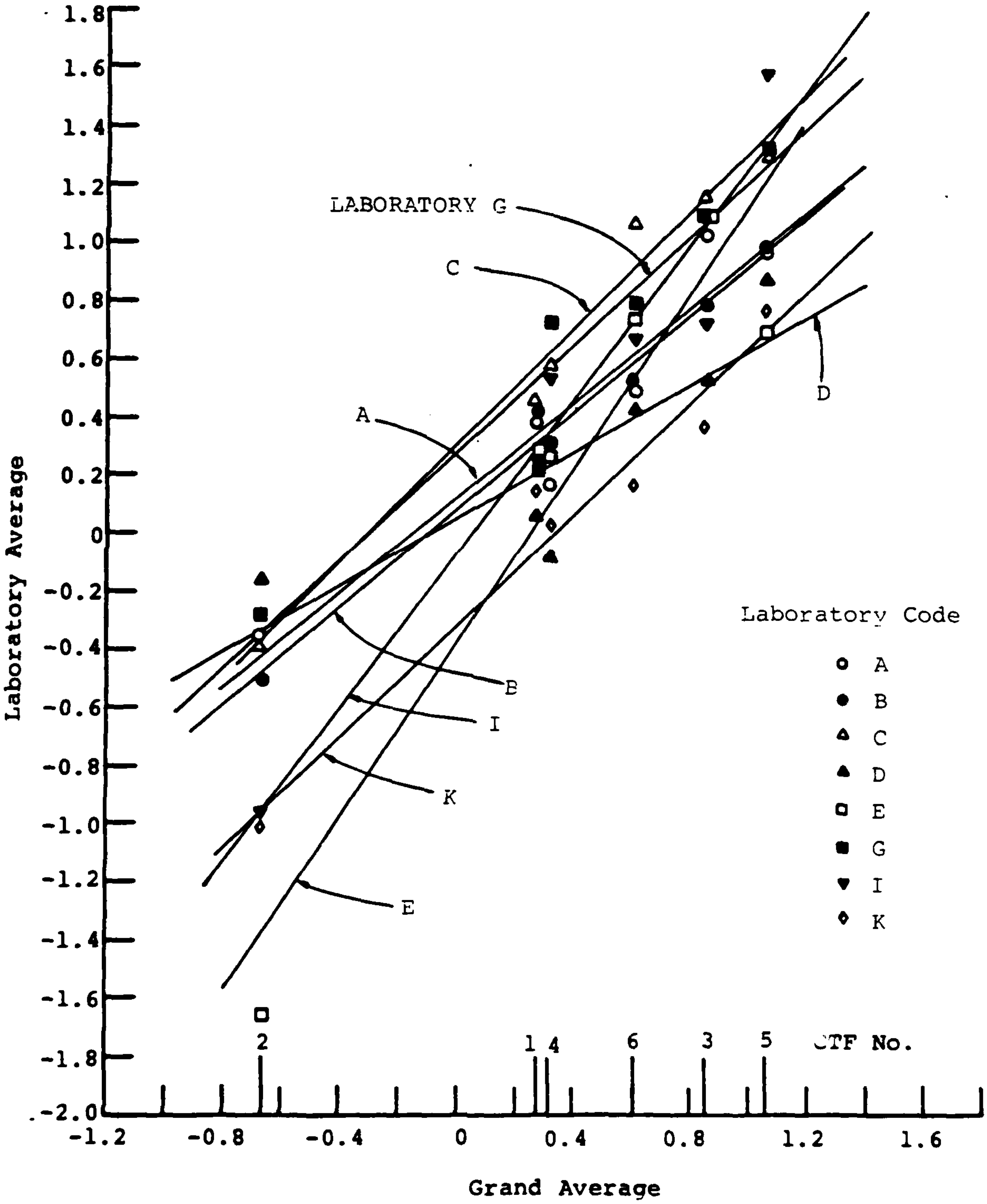


FIGURE 3

RATING FUNCTION LN $(\frac{R}{10-R})$

Laboratory Averages Versus Grand Averages



b. Test Procedure and Operating Conditions

Even though precautions were taken to insure that participating laboratories were using the same procedure draft, engine hardware, data sheets, and operating conditions, a review of these parameters indicated many differences in comparing laboratories. It would appear that part of the reproducibility problem within the program was a result of laboratories not conducting the same test, not using the same hardware, and not controlling operating variables as prescribed.

c. Variables Analysis

At first it would appear that with nine laboratories, six fuels, and duplicate testing an analysis of operating condition variables could be made. Unfortunately, there are more mechanical variables (engine displacement, EGR valves, carburetor gaskets, and carburetor modification) and operating condition variables than there are degrees of freedom. The analysis is confounded by the fact that duplicate ratings are not showing fuel effects, but rather a combination of fuel effects and variable effects. Also, the range in the variables within laboratories is small compared with among-laboratory differences which tend to confound the laboratory effects. Separation of laboratory effects and variable effects independent of fuel effects is not possible because of the very pronounced confounding patterns in the data set. The test program was not designed to study the effect of operating variables, so it is not surprising that the data are confounded.

The analysis does suggest that increasing intake charge temperature at idle and cruise increases carburetor sleeve deposits, while increasing fuel flow at idle and cruise and increasing the number of hours since engine overhaul both decrease deposits.

d. Correction Factor

Even with all the variable differences among the laboratories in general, the laboratories rate fuels similarly, as shown in Figures 2 and 3. Table XVII shows the order each fuel is ranked by each laboratory for sleeve deposit weights. Similarly, Table XVIII shows the ranking order of each fuel by visual deposit rating. Also shown on each table is the average ranking order. No laboratory was more than one ranking position away from the average ranking position of any fuel for either deposit weight or visual rating except for one case.

Because laboratories rank fuels in the same order in spite of the differences in test conditions, it was decided to develop a correction factor for each laboratory to adjust deposit levels to those of the grand average. The correction factor equation and coefficients for each laboratory are shown in Table XIX. Also shown are the errors or uncertainty of the corrected values. Because natural logarithms were used, the error term times 100 represents percent error. Two other error factors shown in the table are grand variance and repeatability. The grand variance consists of repeatability and lack of fit to the regression line. With a good fit, these two error terms should be essentially the same. It is also desirable that repeatability be small.

Using the equation and coefficients shown in Table XIX, corrected deposit weights for each fuel were calculated for each laboratory. These calculated results are shown in Table XX. Also shown is the difference between the corrected value and the grand average. For comparison in parentheses, the differences between the reported weights and grand average are also shown in Table XX. A review of this table shows that, as expected on the average, the corrected values are closer to the grand average than the actual measured values. For individual fuels among the laboratories, however, this is not true -- only thirty-one of fifty-four were closer.

It is believed that the correction factors as presented are appropriate. The lack of fit or wiggle is most troublesome. This comes about in part because all laboratories did not precisely rank all fuels in the same order. From the analysis, it appears that there are many sources of error, not just one dominant error, which can be corrected for. Therefore, the correction factors are probably misleading because they are not correcting for the proper error items. Further, one or two laboratories with poor repeatability or lack of fit can greatly affect the correction factor.

F. Carburetor Visual Rating Method

During the development of the carburetor test procedure, a method was also developed for visually rating the volume of deposits on carburetor throttle body surfaces located below the throttle plate. The method can also be used to rate surfaces above and on the throttle plate itself. This Proposed Carburetor Rating Procedure (see Appendix C) has been submitted to CRC for acceptance as an approved rating method.

TABLE XIX

CORRECTION FACTORS FOR DEPOSIT WEIGHTS
CRC CARBURETOR TEST PROCEDURE PANEL
FUEL CORRELATION PROGRAM

Laboratory	Correction Factor Coefficients[1]			Grand Variance	Repeatability
	Intercept, b	Slope, c	Error		
A	-1.166	1.265	0.26	0.112	0.041
B	-0.498	1.127	0.12	0.018	0.018
C	0.105	1.033	0.21	0.045	0.048
D	0.728	0.723	0.41	0.089	0.089
E	0.400	0.854	0.43	0.138	0.049
G	0.444	0.847	0.52	0.191	0.128
H	0.312	1.003	0.34	0.118	0.009
I	-0.846	1.195	0.54	0.414	0.133
K	0.595	0.923	0.30	0.077	0.035

[1]Corrected ln Deposit Weight = (Measured ln Deposit Weight - b)/a.

TABLE XX

CORRECTED DEPOSIT WEIGHTS
CRC CARBURETOR TEST PROCEDURE PANEL FUEL CORRELATION PROGRAM

Laboratory	CTF-1		CTF-2		CTF-3		CTF-4		CTF-5		CTF-6		Average Difference
	Corrected Deposit Weight	Δ[1]	Corrected Deposit Weight	Δ[1]	Corrected Deposit Weight	Δ[1]	Corrected Deposit Weight	Δ[1]	Corrected Deposit Weight	Δ[1]	Corrected Deposit Weight	Δ[1]	
A	24.3	-5.2 (-11.9)[2]	59.5	-10.3 (-15.0)	5.8	-2.9 (-5.8)	41.8	5.0 (-2.0)	6.3	-0.2 (-3.3)	18.1	3.1 (-2.8)	-1.8 (-6.8)
B	29.4	-0.1 (-2.0)	63.0	-6.8 (-5.0)	7.2	-1.5 (-3.1)	32.7	-4.2 (-5.9)	5.5	-1.0 (-2.4)	16.2	1.2 (-0.9)	-2.1 (-3.2)
C	29.6	0.1 (7.3)	60.2	-9.5 (6.8)	7.8	-0.9 (0.6)	39.7	2.8 (12.9)	5.9	-0.6 (0.5)	12.4	-2.6 (0)	-1.8 (4.9)
D	34.5	5.0 (-2.7)	58.0	-11.8 (-30.8)	11.5	2.8 (3.4)	37.4	0.5 (-8.5)	4.8	-1.7 (-0.1)	11.1	-3.9 (-3.2)	-1.5 (-7.0)
F	27.5	-2.0 (-4.2)	114.7	-44.9 (16.2)	5.5	-3.2 (-2.3)	23.1	-13.7 (-15.1)	8.0	1.5 (2.3)	17.5	2.5 (-2.2)	-10.0 (-1.1)
G	36.2	16.7 (10.6)	75.1	5.3 (-9.3)	12.5	3.8 (4.5)	22.6	-14.2 (-15.0)	4.6	-1.9 (-0.8)	10.4	-4.6 (-3.6)	0.9 (-2.3)
H	21.2	8.3 (-0.2)	64.4	-5.4 (19.3)	5.2	-3.5 (-1.6)	49.2	12.4 (31.2)	7.9	1.3 (4.3)	14.1	-0.9 (4.5)	-0.7 (9.6)
I	34.5	5.0 (0)	77.4	7.6 (7.7)	16.8	8.1 (3.8)	19.6	-17.3 (-21.9)	3.6	-2.9 (-4.5)	13.9	-1.0 (-5.0)	-0.1 (-3.3)
K	23.0	-6.5 (3.2)	60.8	-9.0 (10.5)	5.8	2.9 (0.5)	45.1	8.3 (24.1)	6.8	0.3 (4.1)	16.3	1.4 (9.0)	-0.4 (8.6)

[1]Δ = Corrected Deposit Weight - Grand Average.

[2]Numbers in () are Actual Deposit Weight - Grand Average.

1. Rating Procedure Development

In September 1973, a subpanel was formed by the Carburetor Test Procedure Panel for the purpose of developing a carburetor deposit rating method. Preliminary studies involved rating several dirty field carburetors using several rating methods suggested by various laboratories. This investigation led to the recommendation of a rating procedure that combines the use of color grades to define light deposits and deposit thickness to define heavier deposits over specific carburetor surfaces. The first draft of the method was used by five laboratories for rating nine dirty sleeve inserts from CRC engine tests and nine dirty field carburetors in a round-robin test sequence. Results indicated high variability among raters with standard deviation of the differences from average ratings ranging from 0.4 for the sleeve inserts to 0.9 for the carburetors. The higher standard deviation for the carburetors reflected a higher degree of difficulty in rating dirty carburetors relative to sleeves. The generally large differences among raters were due mostly to misinterpretation of terms describing deposit thicknesses. This resulted in rewriting deposit descriptions to obtain better definition of deposit intensity terms. A visual rating workshop was held in June 1976 at Southwest Research Institute to acquaint laboratories with the rating procedure, and to identify and implement improvements in the method. The following major changes were made to the initial procedure as a result of this workshop:

- Specifications were made defining rating area environment (lighting).
- Deposit intensities in the categories of clean through definite-dark-discoloration was determined with the aid of CRC Diesel Rating Color Chips.
- The following rating aids were developed:
  - a) Gauge to measure depth of deposit on carburetor sleeve inserts.
  - b) Holder for sleeve inserts during ratings.
  - c) An overlay to assist in dividing carburetor sleeves into percentage areas.

A second workshop was conducted several months later using the final rating method which incorporated changes and additions derived from the initial workshop. Table XXI lists the average standard deviations obtained from the initial round-robin investigation and from Workshops 1 and 2. Despite the changes to help reduce variability, standard deviations of carburetor ratings did not change during the course of the rating procedure development. Variability in sleeve ratings was greatly reduced, however, with standard deviations in the final workshop being as low as 0.2.

The Proposed Carburetor Rating Procedure was approved by the Carburetor Test Procedure Panel. It was recommended that the rating method be formally approved by CRC as a CRC rating method.

TABLE XXI

SUMMARY OF AVERAGE STANDARD DEVIATIONS

CRC Proposed Carburetor Rating Procedure

Item Rated	Round Robin 1975	Workshop 1		Workshop 2	
		Session 1	Session 2	Session 1	Session 2
Carburetor					
Below Throttle Plate	0.9	0.94	1.07	0.94	Not Rated
CRC Sleeve					
Insert	0.4	0.71	0.50	0.20	0.19
Carburetor					
Above Throttle Plate	Not Rated	Not Rated		Not Rated	0.40

APPENDIX A

PANEL MEMBERSHIP: INITIAL AND FINAL

CARBURETOR TEST PROCEDURE PANEL - INITIAL MEMBERSHIP

J. J. Malakar, Leader	The Lubrizol Corporation
A. M. Bierylo	Chrysler Corporation
A. D. Brownlow	Southwest Research Institute
R. A. Crane	E. I. DuPont de Nemours & Company, Inc.
F. B. Fitch	Mobil Research and Development Corp.
T. M. Franklin	Rohm and Haas Company
R. E. Kay	Amoco Chemicals Company
W. C. Long	Chevron Research Company
R. J. McConnell	Ford Motor Company
J. B. Retzloff	Ethyl Corporation
H. F. Shannon	Esso Research and Engineering Company

CARBURETOR TEST PROCEDURE PANEL - FINAL MEMBERSHIP

J. J. Malakar, Leader	The Lubrizol Corporation
A. M. Bierylo	Crysler Corporation
M. J. Bilo	Amoco Chemicals Company
T. H. DeFries	Exxon Research and Engineering Company
T. M. Franklin	Consultant
L. M. Gibbs	Chevron Research Company
A. M. Horowitz	Mobil Research and Development Corp.
J. I. Knepper	Tretolite Division
D. L. Lazzari	Southwest Research Institute
W. H. Machleder	Rohm and Haas Company
H. T. Niles	Ford Motor Company
A. H. Peterson	Marathon Oil Company
J. B. Retzloff	Ethyl Corporation
C. R. Stephens	Ashland Petroleum Company
V. Tomsic	E. I. DuPont de Nemours & Company, Inc.

APPENDIX B

CURRENT TEST PROCEDURE:

RESEARCH TECHNIQUE FOR THE STUDY OF CARBURETOR CLEANLINESS CHARACTERISTICS OF GASOLINE

RESEARCH TECHNIQUE FOR THE STUDY OF CARBURETOR CLEANLINESS CHARACTERISTICS OF GASOLINE

October, 1982

A. PURPOSE

This laboratory engine test procedure is designed to provide an accelerated method for investigating and studying the ability of unleaded and leaded gasolines to keep clean the throttle body area of carburetors. These throttle body deposits can affect the idle and low speed metering characteristics of the carburetor and thus influence exhaust emissions, fuel consumption, and performance. This technique evaluates the keep-clean characteristics of gasoline by determining the amount of deposits formed on a removable carburetor throttle body sleeve. Base gasolines and gasolines with additive treatment can be evaluated by this test method.

B. GENERAL TECHNIQUE

The technique involves operating a six-cylinder engine which cycles between idle and medium cruise speed for a total of twenty hours. To accelerate deposit formation, a controlled amount of blowby, induced by enlarging the gaps of the compression rings, is passed into the top of the carburetor mixed with heated intake air. Also, full EGR is applied during the cruise condition. Performance of the test gasoline is judged by the amount of deposits formed on the removable throttle body sleeve as determined by weight and visual ratings. Exhaust emissions (hydrocarbon and carbon monoxide) are also monitored.

C. TEST ENGINE

The test engine is a Ford six-cylinder light-duty truck engine. A 1973 240-CID or a 1977 or 1978 300-CID have been found acceptable.

D. TEST OIL

REO-202-T1* or equivalent SAE-30, 95 VI oil should be used. This oil contains no detergent or dispersant, but does contain zinc dialkyl dithiophosphate and an anti-foaming agent.

E. TEST DEVELOPMENT FUELS

1. Phillips "J" unleaded gasoline.* Results in deposit levels in the 15-40 mg range.

2. MS-08 leaded gasoline was used, but is no longer commercially available. Results in deposit levels in the 80-110 mg range.

F. TEST EQUIPMENT

1. Engine

a. 1973 240-CID Ford, Part No. K113A2L3F, with manual transmission flywheel.

b. 1978 300-CID Ford, Part No. JG251-AA, or 1977 300-CID Ford, Part No. HK251-BA. The major differences between the 240- and 300-CID engines is that the 300 is equipped with a Model YFA carburetor, thermactor air pump, external EGR, and electronic ignition. The 300 engine is modified to conform to the 1973 240 engine as follows:

(1) The Model YFA carburetor must be removed and replaced with a Model YF6384, a service replacement for the 1973 240-CID engine. See Section F.2 for details covering the test carburetor.

(2) The thermactor air pump and air lines must be removed.

(3) The external EGR system is modified by disconnecting the EGR back pressure transducer vacuum lines and connecting the EGR valve vacuum line to the manifold vacuum adapter via a shut-off solenoid. The air inlet port in the EGR spacer is plugged.

(4) The electronic ignition is used as received. Distributor should be D7 TE-12127-TA. Use Motorcraft BSF-42 spark plugs. Alternate plugs are Autolite 745.

The 1978 non-California 300-CID engine, code tag number JG-251-AA, designed for use in a 4,000-pound, 49-state, light truck is recommended over the 1977 300-CID engine.

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* Phillips "J" reference fuel can be obtained from Phillips Petroleum Company, Room 367, Adams Building, Bartlesville, Oklahoma 74004. Contact: H. L. Colopy.

F. TEST EQUIPMENT (Continued)

2. Carburetor

Standard carburetor Part No. D3TF-KA-A-2K-12 is to be used for both the 240 and 300 engines.* The throttle body is modified to receive the aluminum sleeve shown in Attachment 2. Details of a tool for easy removal of the sleeve from the throttle body are given in Attachment 3. Carburetor choke is wired in the open position. The following carburetor gaskets are to be used:

Engine	Service Part Numbers
240-CID	D3TZ-9447-F, -G, -D
300-CID	F3TZ-9447-F, D7TZ-9C477-A D7TZ-9447-C

Attachment 4 shows the placement of these gaskets.

3. Air Cleaner Assembly

The standard air cleaner assembly, Part No. D3TZ-9600-T, with a standard air cleaner element (Motorcraft Part No. C8TF-9601-A or equivalent) is modified as per Attachment 5 to accommodate a blowby connector, an extension sleeve, and thermocouple. Also, the blowby return line hole in the air cleaner is plugged.

4. Intake Air System

A proposed method for introducing humidified air is shown in Attachment 6. It is important that the carburetor inlet pressure is neither under pressure nor under vacuum during idle. Suitable method for controlling inlet air moisture content and temperature is required.

5. Blowby Return System

A specific blowby return system with a calibrated orifice for flow measurement is required. A description of the system is shown in Attachment 7. A drawing of the orifice and orifice-plate is shown in Attachment 8. The crankcase ventilation system must be modified by blocking off the oil filler cap and removing the PCV valve.

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* Completely modified carburetors for testing may be purchased from Carter-Weber, Inc., 2101 Nash Street, Sanford, North Carolina 27330.

F. TEST EQUIPMENT (Continued)

6. EGR System

The following EGR valves are to be used with a timing control mechanism for starting and stopping EGR flow at specified times during the cruise phase:

Engine	Part Numbers	
	Engineering*	Service
240-CID	D4UE-9D475-C2A	D4UZ-9D475A
300-CID	D7TE-9D475-A1A	D7TZ-9D475A

A suggested means of controlling the EGR flow with a solenoid valve attached to the intake manifold vacuum at the automatic transmission vacuum tap is shown in Attachment 9. Attachment 10 shows a typical external connection for the 300 CID valve.

7. Distributor

Use the following distributors:

Engine	Type	Part Numbers	
		Engineering	Service
240-CID	Solid-State**	D3UF-12127BA	D3UZ-12127B
300-CID	Standard Solid-State	D7TE-12127TA	D7TZ-12127T

* Subject to update
** Convert standard distributor to solid-state, using Motorcraft DZ-5002 kit.

F. TEST EQUIPMENT (Continued)

8. Hose Connections

All pressure and vacuum-control hoses are connected according to Ford specifications, except the following:

a. The transmission vacuum hose must be capped.

b. The PCV valve assembly is removed, the connection into the intake manifold plugged, and the rocker cover connection is used for the blowby return system.

c. The hose between the oil filler cap and air cleaner is removed, the connection at the air cleaner plugged, and the oil filler cap is blocked off.

d. The EGR hoses are discarded, carburetor port plugged, and the EGR system is repiped.

9. Oil Filter Adaptor Plate

An adaptor plate is installed in place of the oil filter for test purposes. The adaptor plate for Sequence V-C oil test will fit this engine. The oil filter is used only during run-in of new or rebuilt engines.

10. Exhaust System

Exhaust sampling and back pressure tap is located six inches below the exhaust manifold flange.

11. Throttle Controls

Install suitable throttle controls to allow engine to cycle automatically under the prescribed test conditions. Hydraulic-operated controls timed with a Flexopulse timer are suitable. Attachment 9 shows a suggested method.

12. Power-Absorbing Unit

It is recommended that the engine be connected to a power-absorbing unit of at least 50 BHP and capable of maintaining the prescribed speeds and rate of acceleration.

13. Exhaust Heat-Rise Valve

LOCK THE EXHAUST HEAT-RISE VALVE of the exhaust manifold in an open position to prevent exhaust heat from reaching the intake manifold stove area.

F. TEST EQUIPMENT (Continued)

14. Instruments

a. Thermocouples - The location of thermocouples for water jacket, oil sump, and intake charge temperatures is shown in Attachment 6. Also, see Attachment 6 for location of blowby-air mixture and blowby gas temperature thermocouples. Inlet air temperature thermocouple is located on top of the air cleaner air horn, one inch out from periphery of air cleaner housing.

IMPORTANT: Use 1/8" stainless-steel grounded junction thermocouple, Type J, 3" length.

b. Pressures - Measure intake manifold vacuum at the vacuum outlet fitting on the intake manifold below carburetor adjacent to tap for intake charge thermocouple. Oil pressure tap is located in oil gallery on left rear side of engine.

G. ENGINE REBUILD AND RUN-IN

1. Rebuild

Engine is rebuilt when idle blowby is above the desired level (40 to 60 CFH) or for obvious mechanical reasons (low compression, bearing failure, etc.). Rebuild consists of removing all deposits and replacing all parts necessary to restore clearances and tolerances specified by the engine manufacturer. The only modification to the engine is that piston ring gaps are increased to obtain the desired range of blowby. However, this modification is made after the engine is run-in under the conditions listed below using normal piston ring gaps.

2. Parts Cleaning

Parts cleaning is a critical operation.
The head, block, and all parts to be used for a rebuild are cleaned by removing all deposits and soaking for two hours in Oakite Carbosolv. These parts are then rinsed in hot water and sprayed with Stoddard Solvent. All parts are then air-dried, and all finished surfaces coated with the same SF oil to be used for run-in.

3. Run-In

Use the following 4-3/4-hour run-in schedule on a new or rebuilt engine. A conventional SF oil should be used.

G. ENGINE REBUILD AND RUN-IN (Continued)

Step No.	Time Per Step (Min.)	Total Time	RPM	Int.Man.Vac., Inches,Hg	Remarks
1	0:15	0:15	1000	19.5	Water Jacket 195±5°F
2	0:15	0:30	1200	19.0	Oil sump 270°F max
3	0:15	0:45	1400	18.5	
4	0:15	1:00	1600	18.0	Use oil filter for run-in only
5	0:15	1:15	1800	17.0	
6	0:30	1:45	2000	16.0	
7	0:15	2:00	2200	15.0	
8	0:15	2:15	2400	14.0	
9	0:15	2:30	2600	13.0	
10	0:15	2:45	2800	12.0	
11	0:45	3:30	3000	10.0	
12	0:15	3:45	3200	9.0	
13	0:15	4:00	3400	8.0	
14	0:15	4:15	3600	7.0	
15	0:15	4:30	3800	6.0	
16	0:15	4:45	4000	5.0	

After run-in, flush engine with new REO-202-T1 oil or equivalent.

4. Ring Gaps

Check idle blowby and regap compression rings to establish 40-60 CFH blowby limits, as described in Item H.2.b.

H. TEST PROCEDURE

1. Operational Settings

a. 240-CID

(1) Spark plug gap: 0.035 in. (Motorcraft BSF-42 or Autolite 745)

(2) Converted electronic ignition does not require dwell setting.

b. 300-CID

(1) Spark plug gap: .042-.048 (Motorcraft BSF-42 or Autolite 745).

(2) Electronic ignition does not require dwell setting.

H. TEST PROCEDURE (Continued)

2. Preparation of New or Rebuilt Engine for Test

a. New engines and rebuilt old engine should be run-in using the 4-3/4-hour run-in schedule described under Item G.3.

b. Ring Gaps - After run-in, measure blowby under standard engine-idle conditions. If necessary, increase gaps of compression rings to provide 40-60 CFH at idle. Usually, ring gaps of about 0.050 inch are required.

3. Preparation for Start of Test

a. Clean blowby and EGR orifices. Also, clean vertical surfaces of the EGR spacer under carburetor, as well as inside of intake manifold riser by wiping. Clean upper throttle-body areas of carburetor. Use suitable solvent as noted in G.2.

b. Install carburetor with clean weighed sleeve (see Item H.7.c (5) and (6) for cleaning procedure).

c. Check air filter element; replace after 10 tests.

d. Refill crankcase with weighed new REO-202-T1 oil.

e. Install new spark plugs properly gapped.

f. 240-CID Engine Timing - At 700 RPM, engine timing should be set at 6°ATDC with vacuum lines connected, and at 2000 RPM, engine timing should be 20 ± 2° with vacuum lines connected.

g. 300-CID Engine Timing - Basic engine timing should be set at 6°BTDC at 700 RPM with vacuum lines disconnected. No engine timing is specified at 2000-RPM.

h. Check operation of the EGR system; the EGR valve should be 100% open with 10 inch Hg vacuum.

i. Insure that a non-vented oil fill plug is used in the rocker-arm cover during engine test operation.

j. Remove oil dip stick and plug tube with a small rubber stopper.

k. Flush fuel system to the carburetor with a sufficient amount of test fuel to prevent possible fuel/additive carryover effects from the previous test run.

H. TEST PROCEDURE (Continued)

4. Start of Test

a. Start engine and warm up for 2 to 3 minutes at (700 RPM) idle with 0-1 BHP followed by 10 minutes at 2000 RPM with 10 BHP and full EGR operation.

b. Adjust engine to operate under the following test conditions at start of test:

Test Conditions

	Idle	Cruise
Time at given throttle setting, min.	3.0	7.0
Engine Speed, RPM	700 ± 15*	2000 ± 50***
% CO	1.5 ± 0.2*	Record
Fuel Flow, lb/hr	3.75 ± 0.25**	9.5 ± 0.1***
BHP	Adjust**	Adjust***
Blowby, CFH	30 ± 2	Record
EGR	None	Full
Temperature, °F:		
Intake Air	150 ± 5°	150 ± 5°
Blowby Gas	185 ± 2°	185 ± 2°
Water Jacket	190-195°	190-195°
Oil Gallery	190-230°	190-230°
Oil Pressure, psig	Record	20 min.
Intake Air Humidity, gr/lb	80 ± 5	80 ± 5
Exhaust Back Pressure, in. H_2O	Record	6.5 ± 0.5
Fuel Pressure, psi	5 max.	5 max.

Timing of Engine Events During Cruise Operation

Elapsed Time	Engine Event Sequence
At 0:00	Open throttle to a position that will give 2000 RPM at 9.5 ± 0.1 lb/hr fuel flow under load.
From 0:03 - 0:05 Min.	Accelerate to 2000 RPM and apply load as required.
At 0:05 Min.	Apply full EGR.
At 7:00 Min.	End of cruise cycle; stop EGR, close throttle, decrease dyno load to idle condition.

* See 5.a (1)
** See 5.a (2)
*** See 5.b (1)

H. TEST PROCEDURE (Continued)

5. Operation of Engine During Test

a. During first hour:

(1) Adjust idle-speed screw and air-fuel mixture screw to give 700 ± 15 RPM and 1.5 ± 0.2% CO.

(2) Check fuel flow and apply dynamometer load if necessary to obtain fuel flow of 3.75 ± 0.25 lb/hr.

(3) Repeat 5.a-1 and 5.a-2 until all three idle parameters are within acceptable limits.

(4) Make no further idle adjustments (speed, air-fuel mixture, or load) after first hour of test.

b. Remainder of test:

(1) Adjust cruise phase dynamometer load and engine throttle position to give 2000 RPM and 9.5 ± 0.1 lb/hr fuel flow with full EGR and 6.5 ± 0.5 inch H_2O exhaust back pressure. (Readjust cruise load, speed, fuel flow, and exhaust back pressure hourly, if necessary, during test.)

c. *Data to be recorded:*

	Measurement Intervals (hours)	
	Idle	Cruise
Engine Speed, RPM	1	1
Manifold Vacuum, in.Hg.	1	1
Load, BHP	1	1
Fuel Flow, lbs/hr	1	1
Temperatures, °F:[1]		
Intake Air	1	1
Blowby Gas	1	1
Blowby-Air Mixture	1	1
Intake Charge[2]	1	1
Water Jacket	1	1
Oil Gallery	1	1
Emissions[3]		
% CO	Start & End	Start & End
HC ppm C_6	Start & End	Start & End
Blowby, CFH[4]	4	
Oil Pressure, psi	4	4
Exhaust Back Pressure, in H_2O		4
Intake Air Humidity, gr/lb	4	
Fuel Consumption[5], lbs		

[1,2,3,4,5] See page B-11 for explanation of footnotes.

H. TEST PROCEDURE (Continued)

5. Operation of Engine During Test (Continued)

c. (Continued)

Explanation of footnotes found on page 10:

[1]Measure idle temperatures at 2 minutes into the idle phase, and measure cruise temperatures at 5 minutes into the cruise phase.

[2]Intake charge temperature should be between 270°F to 385°F for both the 240-CID and 300-CID engines at the cruise phase conditions. If temperature is not found to be between this range, inspect EGR system for problems and/or replace EGR valve.

[3]Measure % CO and HC, ppm as C_6, at start and at end of test. Specify method of measuring HC and CO. These emissions can be obtained at more frequent intervals and be used as a means of monitoring the progress of the test.

[4]Determine natural engine blowby level at idle and cruise phases during the first hour of each run, and at idle after every four hours.

[5]At end of test, determine total fuel usage, if possible.

6. Test Duration

The test is completed at the end of twenty hours of cycling.

7. End of Test

a. Shutdown engine and let stand for 5 minutes.

b. Drain crankcase for 15 minutes. Weigh and record weight of oil, and calculate total oil consumption on weight basis.

c. Carburetor Sleeve

(1) Remove idle fuel screw. Then, carefully remove aluminum throttle body sleeve without disturbing deposits, using the Sleeve Remover Tool described in Attachment 3.

(2) Remove any deposits from external surface of sleeve by wiping with acetone. Then, dip sleeve in pentane for 30 seconds, dry 5 minutes in 200°F oven and 30 minutes in desiccator, then weigh.

(3) Rate deposits by the proposed CRC visual carburetor rating procedure. See Appendix 1 for the proposed procedure.

(4) Photograph throttle body sleeve (3 x 3 color), if possible.

H. TEST PROCEDURE (Continued)

7. End of Test (Continued)

c. Data to be recorded (Continued)

(5) Clean sleeve by wiping or brushing away deposits, using suitable solvent as noted in G.2. Remove solvent film by rinsing in hot water and dipping in acetone and pentane. Prepare for weighing as described in Item H.7.c (2).

(6) Weigh cleaned sleeve. Weight should be within 0.1 mg of clean weight from previous test. Reclean if greater than 0.1 mg.

d. Clean upper throttle body areas of the carburetor by using suitable solvent as noted in G.2. This area should be cleaned after each test run.

8. Method of Reporting Data

Test results should be reported as indicated on the sample form included as Attachment 1. In general, the data required include weight and rating of carburetor sleeve deposits, exhaust emissions at start and end, and pertinent engine operating data.

SUMMARY DATA

CRC CARBURETOR CLEANLINESS TEST SUMMARY

Test Lab ______________________________

Test Identification ______________________________

____

Test Fuel ______________________________

RESULTS

Sleeve Deposit Wt., mg ______

Sleeve Rating (10 = clean) ______

Emissions		Start	End	Δ Change
%CO	Idle			
	Cruise			
HC, ppm C_6	Idle			
	Cruise			

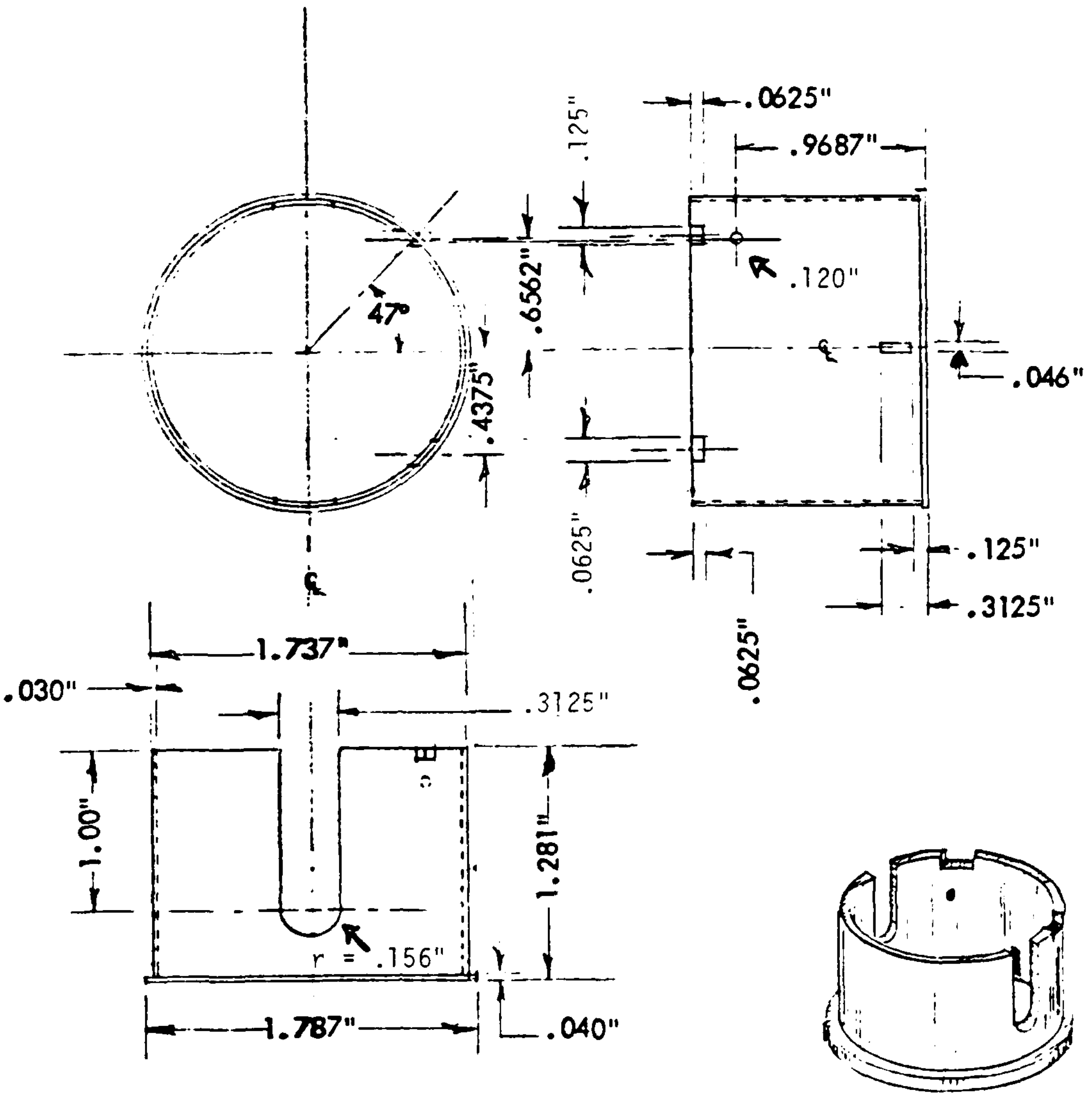
OPERATING CONDITIONS		Min.	Max.	Avg.*
Fuel Flow, (lb/hr.)	Idle			
	Cruise			
Man. Vac., (in Hg)	Idle			
	Cruise			
Speed, (RPM)	Idle			
	Cruise			
Load, (BHP)	Idle			
	Cruise			
Blowby, (CFH)	Idle			
Temperatures (°F)				
Intake Charge	Idle			
	Cruise			
Blowby Gas	Idle			
	Cruise			
Blowby-Air Mix	Idle			
	Cruise			
Air Inlet	Idle			
Water Jacket	Idle			
Oil Gallery	Idle			
Exhaust Back Pressure, (in. H_2O)	Cruise			
Humidity, (gr/lb. air)	Idle			
Oil Pressure, (psi)	Idle			
Fuel Pressure, (psi)	Idle			
Total Oil Usage, (lbs.)				

REMARKS:

*Average of all except 1st hour readings obtained.

REMOVABLE THROTTLE BORE SLEEVE

CRC CARBURETOR CLEANLINESS TEST

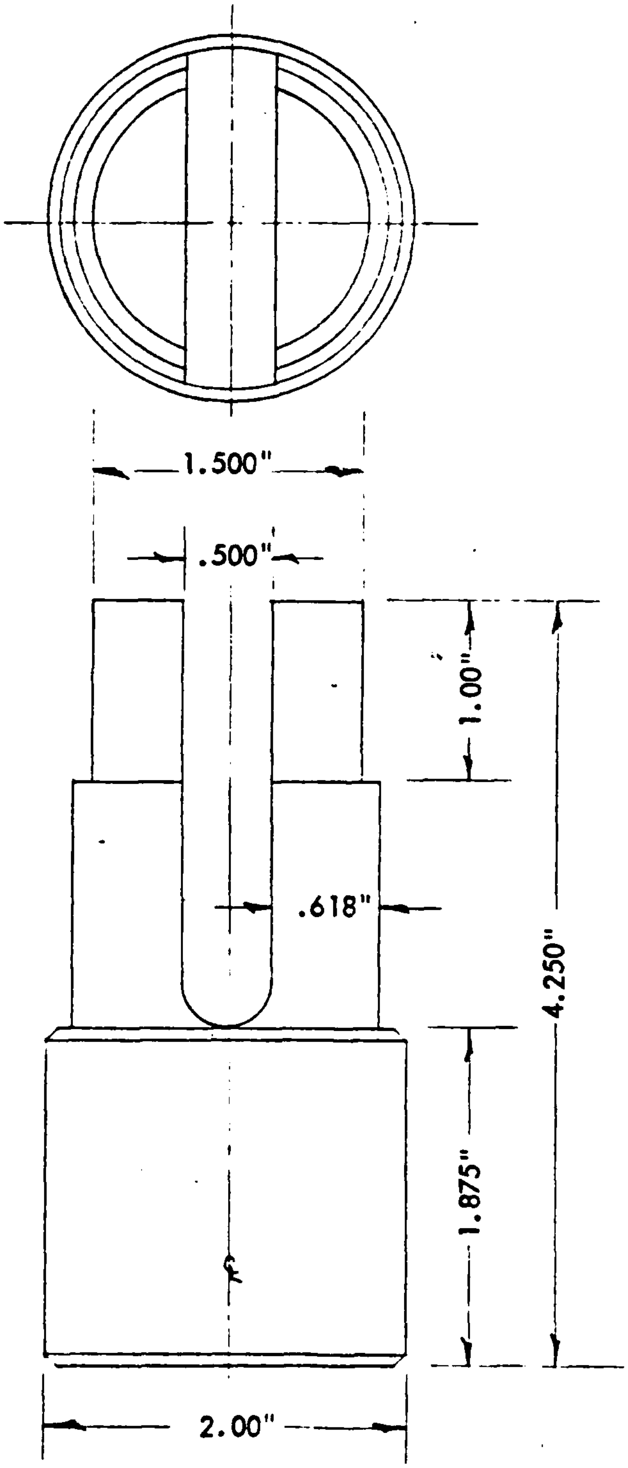


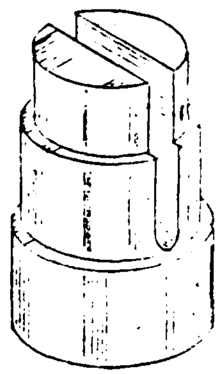
Pictorial View

Material: Aluminum Rod #2024-T351 Aircraft Alloy

SLEEVE REMOVER TOOL

CRC CARBURETOR CLEANLINESS TEST

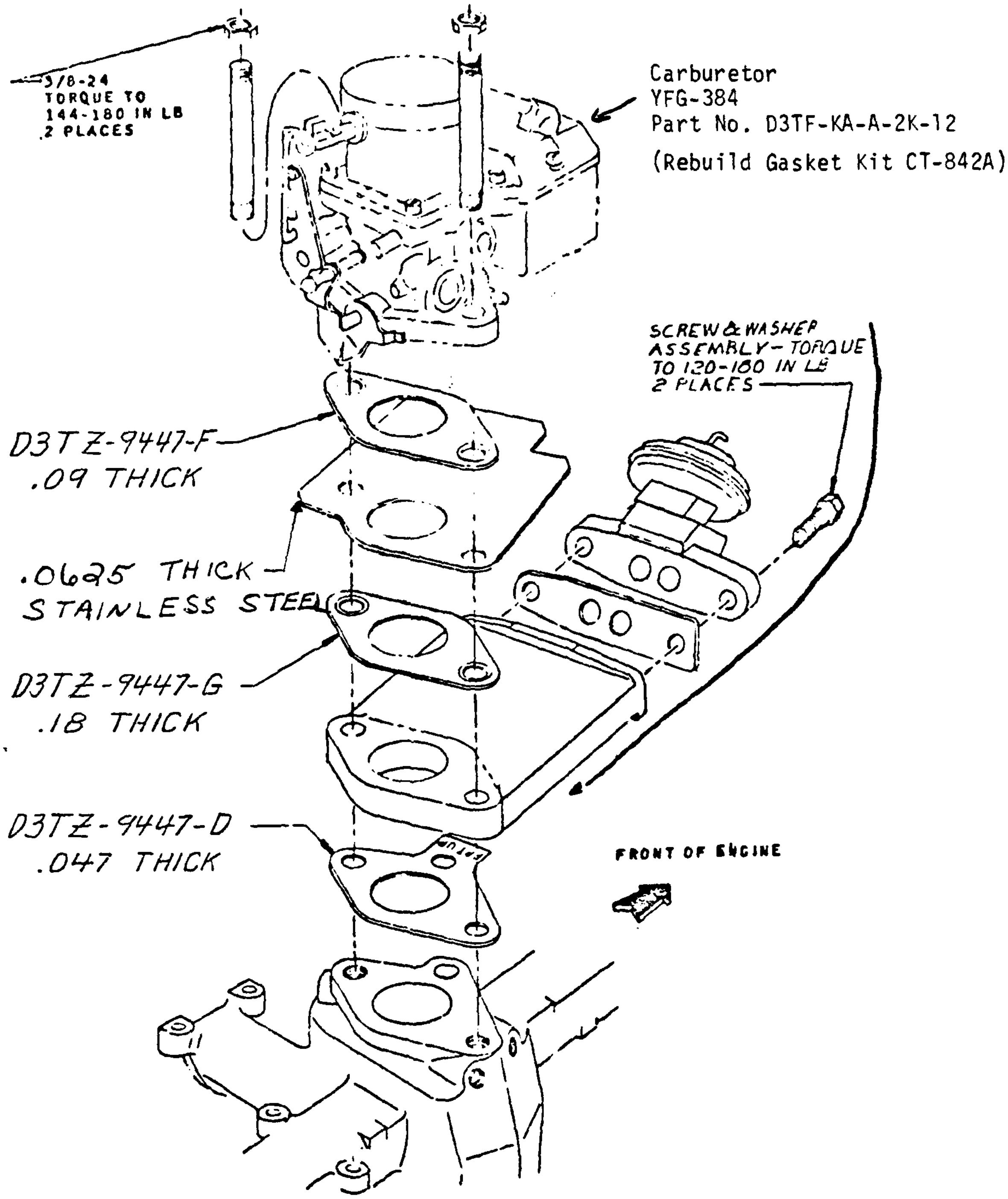




Pictorial View

Material: Micarta (A Canvas Back Plastic

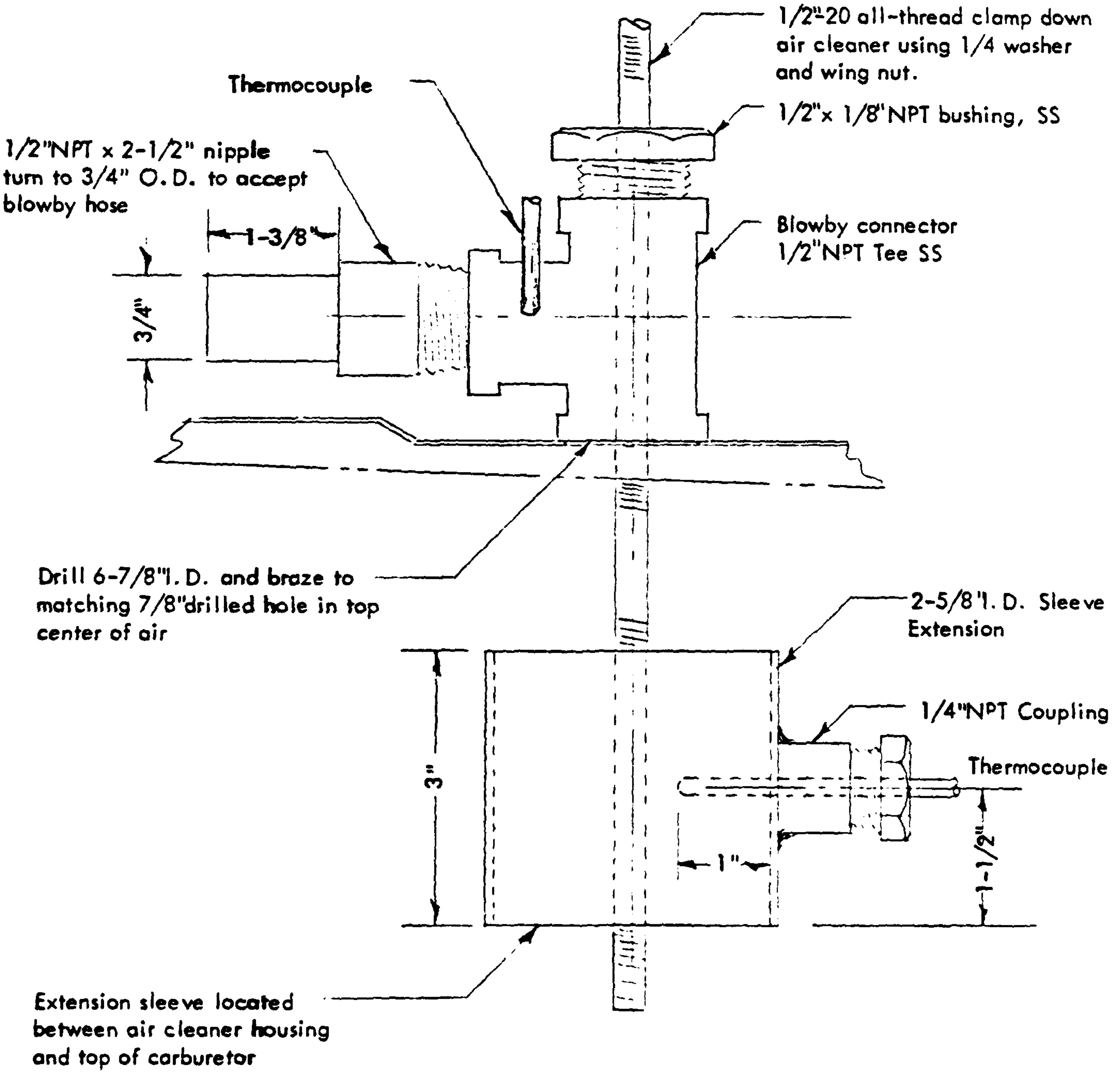
INSTALLATION OF CARBURETOR SPACER,
VALVE ASSEMBLY & GASKETS FOR EGR SYSTEM



NOTE - PART NUMBERS ARE SERVICE PART NUMBERS

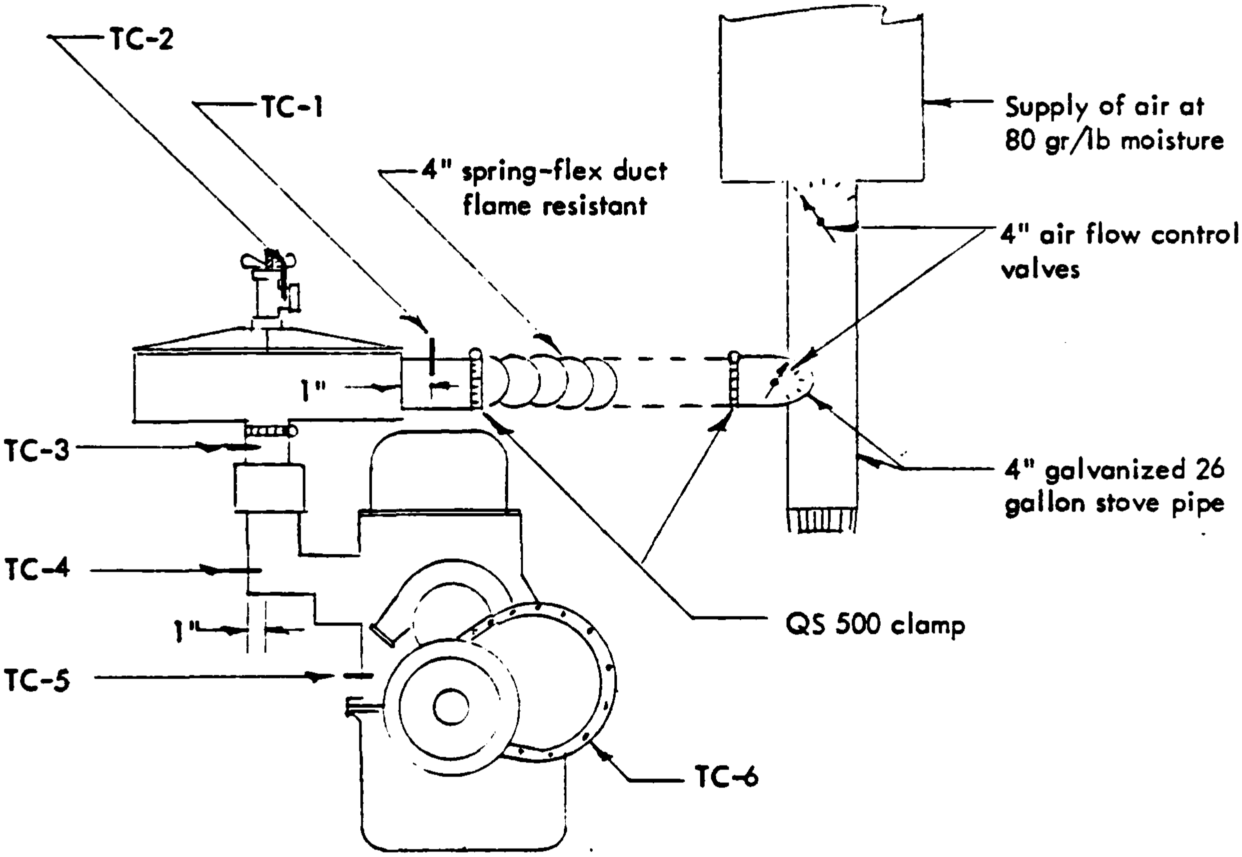
BLOWBY CONNECTION AND EXTENSION SLEEVE

CRC CARBURETOR CLEANLINESS TEST



PROPOSED INTAKE AIR SYSTEM

CRC CARBURETOR CLEANLINESS TEST



THERMOCOUPLES

TC-1 Intake air - located on top of the air cleaner air horn, one inch out from the periphery of air cleaner housing.
TC-2 Blowby gas - located at the blowby connection to the air cleaner housing.
TC-3 Blowby-air mixture - located at the extension sleeve between the air cleaner housing and carburetor.
TC-4 Intake charge - located in place of the vacuum tap for brakes and steering. Temperature obtained is above the center of the stove area.
TC-5 Water jacket - located in the same position as water temperature light sensor.
TC-6 Oil - located in oil gallery in place of a 3/8 inch Allen Head pipe plug.

FIXED ORIFICE SYSTEM FOR BLOWBY RETURN LINE

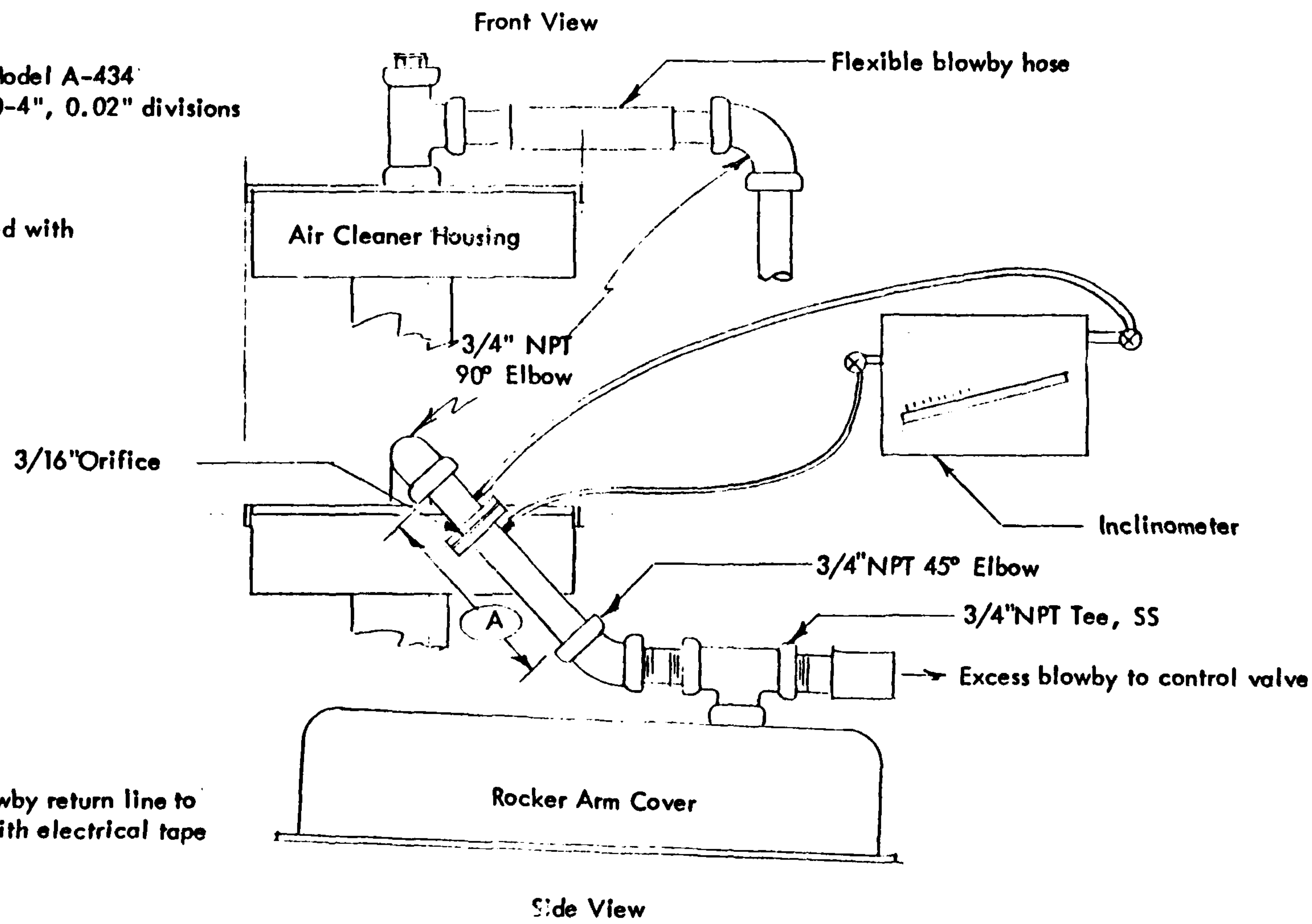
CRC CARBURETOR CLEANLINESS TEST

Inclinometer

Merion Industries Co. Model A-434
Red Oil sp.gr. 0.827, 0-4", 0.02" divisions

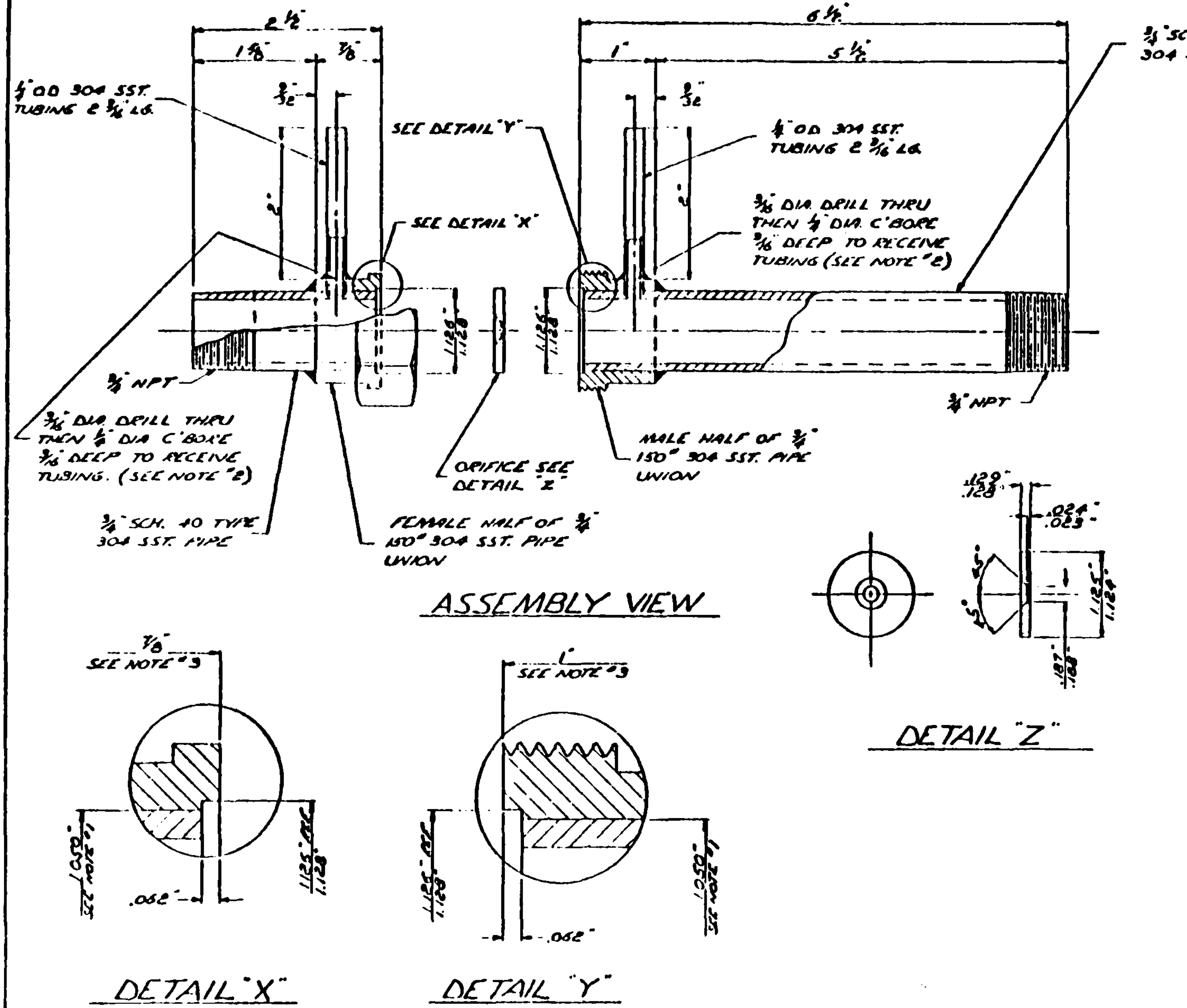
Heating Tape

Blowby return line lagged with electrical heating tape



A - Length of blowby return line to be lagged with electrical tape

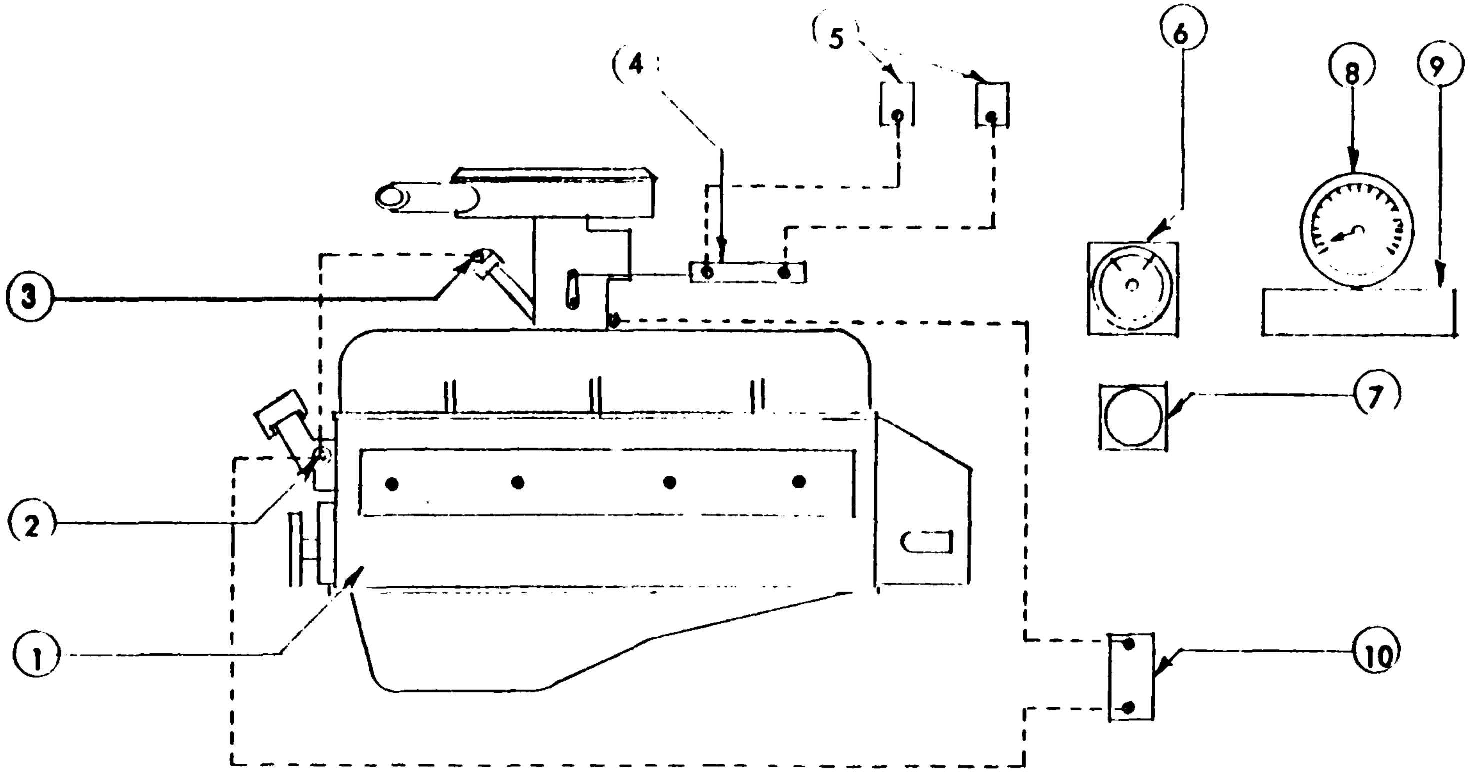
ORIFICE HOLDER ASSEMBLY



NOTES:

1. BORE UNION TO GIVE EASY PRESS FIT OVER PIPE.
2. DRILL HOLE IN UNION, INSTALL 1/4" OD TUBING & WELD AS SHOWN AFTER WELDING 3/4" PIPE TO UNION.
3. FACE UNION TO DIMENSION SHOWN & C'BORE .062" DEEP AFTER WELDING 3/4" PIPE TO UNION.

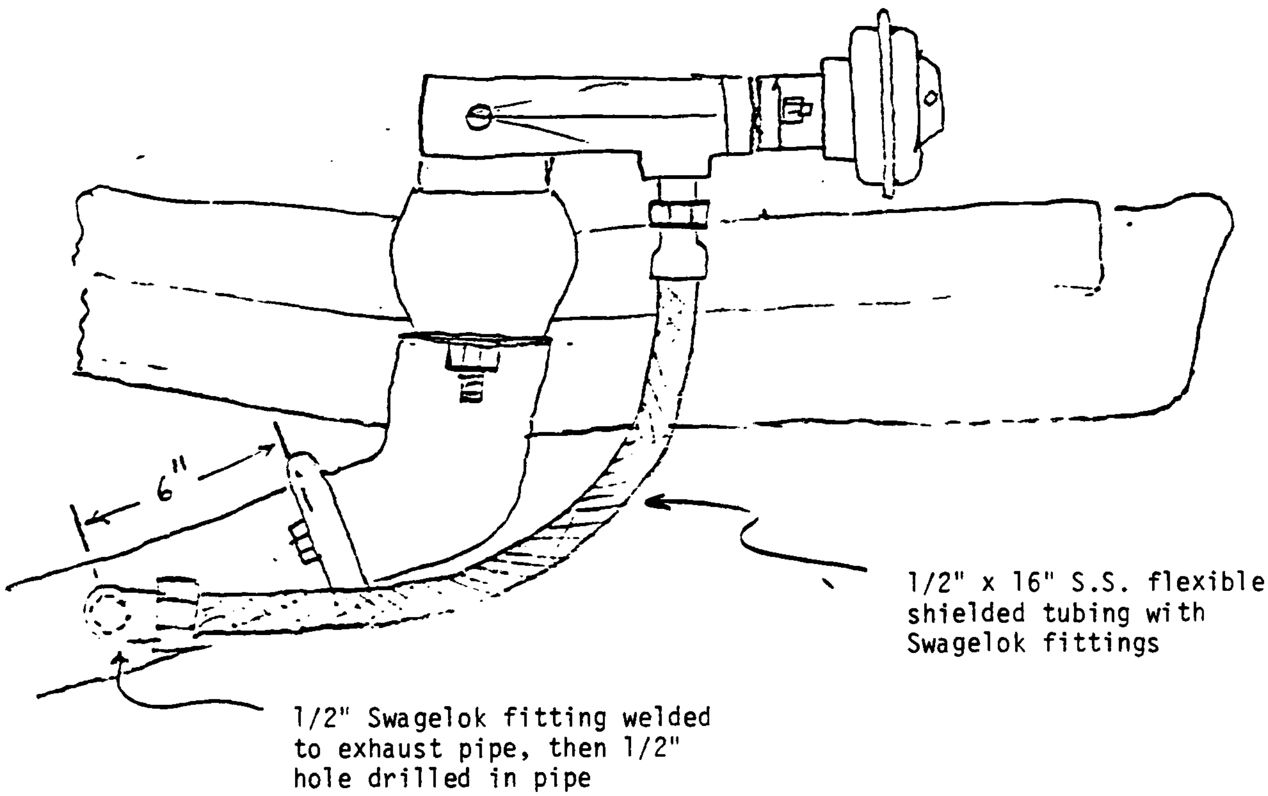
SUGGESTED THROTTLE AND EGR CONTROL SYSTEM



---- Pneumatic Circuits

1. Ford 6 Cylinder Engine
2. Cooling Jacket EGR Control
3. EGR Control Valve
4. Throttle Control Cylinder
5. 120 Volt Skinner Solenoid Valves 1/16" Orifice
6. Flexopulse 20 Minute HG94A Timer
7. Singer TDAF-15 S Timer
8. Dynamometer
9. Load and Speed Control Circuit
10. 120 Volt Skinner Solenoid Valves 1/16" Orifice

EGR VALVE & BODY



APPENDIX C

PROPOSED CARBURETOR RATING PROCEDURE

PROPOSED CARBURETOR RATING PROCEDURE

Introduction

A procedure is described for assigning numerical ratings to deposits found on carburetor throttle body surfaces. For the purpose of this discussion, the throttle body surface is divided into two areas: that area below the line inscribed by the normally closed position of the throttle plate; and that area above the closed throttle plate extending to the beginning of the nozzle contraction section of the carburetor. The application of this procedure to the area above the closed throttle plate is further developed in Attachment I of Appendix C. This procedure may also be used to assign a numerical rating to both the upper throttle plate surface and to the lower throttle plate surface.

I. Preparation of Parts

Parts to be rated should be disassembled as much as is practical. The aluminum throttle body inserts (sleeves) used in the CRC Carburetor Cleanliness Test are normally removed from the throttle body for weighing and should be rated immediately after weighing. Carburetors should be removed from the engine before rating; however, it is recognized that in the field this may not always be possible.

Extreme care should be exercised during disassembly so as not to disturb deposits.

Surfaces to be rated should be briefly soaked in a volatile saturated hydrocarbon solvent (e.g., hexane) to remove oily surface films. Do not flush the surfaces, as flushing may physically remove deposit. A soaking procedure is specified in the CRC Carburetor Cleanliness Test Procedure.

II. Rating Environment

A. Use a desk lamp with two "cool white" 15-watt fluorescent lights (Dazor Manufacturing Corporation, Part No. UL-P-2136-16) with a white background.

B. Sleeve or carburetor should be hand-held at such an angle to let maximum viewing and light into the rated area at an approximate distance of 2 inches beneath the fluorescent bulbs.

III. Deposit Rating

A. Intensity of deposits in the categories of clean through definite dark discoloration shall be determined with the aid of the CRC Diesel Rating Color Chips. The five deposit level categories are defined as follows:

1. Clean:

That surface condition which has the same appearance as that of a sleeve which has just been prepared for test. This condition can be related to the clean or minimum Very Light Amber Lacquer (VLAL) chip depending upon the before-test condition. Before-test condition usually can be observed at some point above the throttle plate area on the sleeve.

2. Light Discoloration:

That surface condition which has any deposit at all up to the intensity value of the CRC Diesel maximum Amber Lacquer (AL) chip.

3. Dark Discoloration:

That surface condition which has an intensity value from a minimum of the maximum AL chip to the maximum of the maximum Black Lacquer (BL) chip with no appreciable depth (<0.001 inch).

4. Deposit Thickness <0.015 inch:

That surface condition which usually has a granular or carbonaceous consistency <0.015 inch. It may be noted that some deposits in this category have a very smooth-shiny texture similar to that of black lacquer, but definitely have a visible thickness.

5. Deposit Thickness >0.015 inch:

That surface condition which has a deposit of >0.015 inch. Deposits in this category are usually granular or carbonaceous in appearance.

B. Weighting factors for the five deposit levels defined above are as follows:

1. Clean - 0	4. < 0.015 inch - 3
2. Light - 1	5. > 0.015 inch - 4
3. Dark - 2	

IV. Merit Rating

The rater determines the percentage of the throttle body left side area covered by deposits of each of the five categories of Section III. The left side Total Deposit Number is the sum of the products of area covered and the corresponding weighting factors. This sum is multiplied by the percent available area, which is the percentage of total, below-throttle-plate area available for deposit that lies on the left side. The right side is rated similarly. The Carburetor Merit Rating is:

$$\text{Merit Rating} = 10 - \left[\frac{(\text{Total Deposit Number X \% Available Area) Left Side}}{4000} + \frac{(\text{Total Deposit Number X \% Available Area) Right Side}}{4000}\right]$$

The CRC Carburetor Cleanliness aluminum test sleeve has 40 percent left side available area and 60 percent right side available area. To determine the division of left and right side available area for most other carburetors, measure the depth of the closed throttle plate (at center of plate) from the bottom surface, for each side. The Percent Available Area is calculated as follows:

$$\text{\% Available Area, Right} = 100 \text{ X } \frac{\text{Right Depth}}{\text{Right Depth + Left Depth}}$$

$$\text{\% Available Area, Left} = 100 \text{ X } \frac{\text{Left Depth}}{\text{Right Depth + Left Depth}}$$

For two- and four-barrel carburetors, the Total Deposit Numbers are replaced by deposit numbers averaged over the number of barrels.

V. Rating Aids

Several devices have been developed to aid in rating the aluminum inserts used in the proposed CRC Carburetor Detergency Test. These include: a depth gauge to aid in characterizing deposit thickness; and a transparent grid to aid in determining the area to be assigned a particular intensity value. The preparation and use of these aids is outlined in Attachment II of Appendix C.

Attachment I

PROPOSED ABOVE THE THROTTLE PLATE RATING PROCEDURE

Using the procedure proposed for carburetor throttle bodies and CRC test sleeves, the following changes are proposed for above the throttle plate ratings:

1. Area to be rated:

   Above the line indicating closed throttle plate to the top of the casting (for divided castings/sleeves) or to the beginning of the nozzle contraction section (for single castings).

2. Estimate of area available for rating:

   % Upper Left Side Available Area = 100 - Left Side Below Throttle Plate

   % Upper Right Side Available Area = 100 - Right Side Below Throttle Plate

3. Use of the same weighting factors and color intensities.

4. Indicate on rating sheet that rating is for "Above Throttle Plate."

RATING AIDS

A. The following are suggested as aids for rating the CRC aluminum inserts:

1. Depth gauge (note: use of gauge may damage deposit -- not recommended for repeated ratings of the same sleeve).

   Starrett Cat. No. 1015 A-431

   See catalog for rounded lower surface or machine a 1/8-inch diameter hemispherical lower surface.

   Recommended Procedure for Use:

   Hold the insert in one hand, the gauge in the other; zero the gauge on a clean area of insert near the deposit to be rated. Gently measure the thickness of the deposit. (Soft deposits may be disturbed by the tension of the dial gauge.)

2. Transparent deposit outline divided into 5-percent grids for the left and right sides of the insert area below the throttle plate (see Figure C-1).

   Preparation: Place a sheet of clear plastic (0.005 inch thick), such as used in report covers, over Figure C-1 and trace the outline and grid using a razor blade or other sharp stylus. Cut the outer perimeter of the outlined area with a razor blade or scissors. Trim the ends so that when joined, the cylinder will fit easily into an insert without scraping off deposit. Join the ends with a clear plastic tape.

   Use: Insert the cylinder into the insert to be rated. Line up the upper curve line with the outline of the closed throttle plate. Each grid area represents 1/20 of the left/right side of the insert below the throttle plate. This device is particularly useful in estimating large areas of uniform deposit on the insert.

B. CRC Diesel Rating Chips

The CRC Diesel Rating Chips used to characterize the deposit color can be purchased through the Coordinating Research Coundil. Inc., 219 Perimeter Center Parkway, Atlanta, Georgia 30346.

FIGURE C-I

TRACE INSERT OUTLINE ON PLASTIC

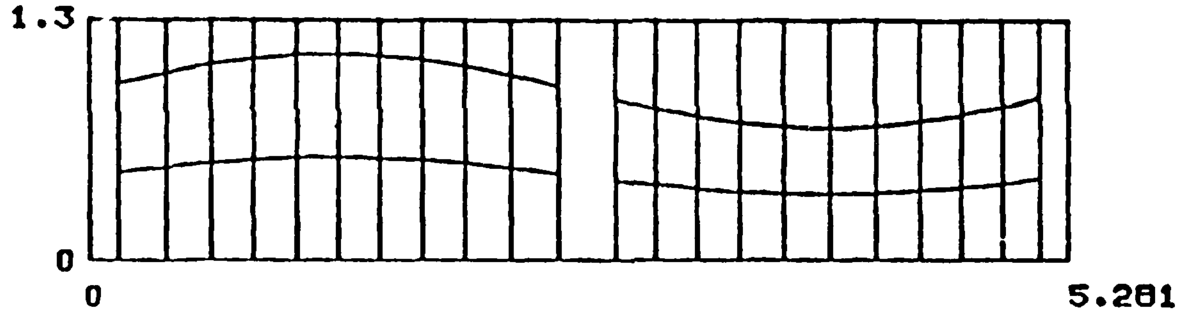


TABLE C-I

PROPOSED CRC CARBURETOR RATING SHEET

CARBURETOR MAKE__________ BBLS.__________ DATE__________ TEST #__________ RATER__________

USE SEPARATE SHEET FOR: PRIMARY BBLS.__________ SECONDARY BBLS.__________

COLOR/DEPOSIT RATING	Linkage[1] Barrel: %Area x Left[2] Side	Linkage[1] Barrel: %Area x Right[1] Side	Linkage[1] Barrel: Weighting Factor	Linkage[1] Barrel: = Deposit No. Left Side	Linkage[1] Barrel: = Deposit No. Right Side	Non-Linkage Barrel: %Area x Left Side	Non-Linkage Barrel: %Area x Right Side	Non-Linkage Barrel: Weighting Factor	Non-Linkage Barrel: = Deposit No. Left Side	Non-Linkage Barrel: = Deposit No. Right Side
Clean (no visible deposits)			0	0	0			0	0	0
Light discoloration (Max.A.L)			1					1		
Definite (dark) discoloration (< .001" thick)			2					2		
Deposit < .015" > .001" thick			3					3		
Deposit > .015" thick			4					4		
	100%	100%	Total Deposit Number			100%	100%	Total Deposit Number		

% OF TOTAL AREA BELOW THROTTLE PLATE AVAILABLE FOR DEPOSIT (CRC Test Sleeves: 40%Left; 60%Right)[3]

$$\%\text{Left Side} = 100 \times \frac{\text{Left Depth}}{\text{Left + Right}} = \_\_\_\_\%;\quad \%\text{Right Side} = 100 \times \frac{\text{Right Depth}}{\text{Left + Right}} = \_\_\_\_\%$$

FOR 2/4 BBL. CARBURETORS: AVE.RIGHT DEPOSIT NO. = 0.5 x (RIGHT LINKAGE BARREL + RIGHT NON-LINKAGE BARREL) = __________

AVE.LEFT DEPOSIT NO. = 0.5 x (LEFT LINKAGE BARREL + LEFT NON-LINKAGE BARREL) = __________

$$\text{CARBURETOR MERIT RATING} = 10 - \frac{(\text{AVE.LEFT DEPOSIT NO.} \times \%\text{AVAILABLE AREA}) + (\text{AVE.RIGHT DEPOSIT NO.} \times \%\text{AVAILABLE AREA})}{4000}$$

$$= 10 - \frac{(\quad \times \quad) + (\quad \times \quad)}{4000} = 10 - \frac{(\quad) + (\quad)}{4000} = 10 - \_\_\_\_ = \boxed{\quad}$$

NOTES

1. The right side of the carburetor/sleeve is the one with idle fuel ports, transfer slot, and vac. ports. The linkage barrel is the barrel adjacent to the carburetor linkages.
2. The left side of the carburetor/sleeve has no holes.
3. The CRC Carburetor Cleanliness Test Aluminum sleeve is considered to have 40% Left Side Available Area, 60% Right Side Available Area.

APPENDIX D

DETAILED FUEL COMPOSITIONS:

UNLEADED FUEL CORRELATION PROGRAM

FUEL 009123 DETAILED COMPOSITION

CRC-CTF-1

CARB. NUMB.	NORMAL PARAFFIN	ISO-PARAFFIN	NAPH - - THENES	OLEFINS	AROMATIC AR. RN.	UNCLASS. HC	TOTALS	CYCLO-PENTANES	CYCLO-HEXANES
3	0.06	******	******	0.0	******	******	0.06	******	******
4	2.64	0.52	******	0.48	******	******	3.64	******	******
5	2.50	20.58	0.16	4.31	******	******	27.55	0.16	******
6	0.43	2.33	0.74	2.18	0.54	******	6.23	0.65	0.10
7	1.45	2.69	1.39	0.86	22.33	******	28.71	1.13	0.26
8	0.88	3.92	0.95	0.02	11.45	0.19	17.41	0.71	0.24
9	0.37	2.23	0.0	0.0	8.64	0.23	11.47	0.0	0.0
10	0.0	0.22	0.0	0.0	3.06	0.71	3.99	0.0	0.0
11	0.10	0.07	0.0	0.0	0.77	0.0	0.93	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	8.43	32.56	3.25	7.85	46.78	1.13	100.00	2.65	0.60

SUBGROUPS					
LT	5.63 C3-6	23.43 C4-6	0.90 C5-6	6.97 C3-6	34.32 C6-8
HY	2.80 C7+	9.32 C7+	2.34 C7+	0.88 C7+	12.46 C9+

ISO-PAR +NAPHTH		
LT		24.33 C4-6
HY		11.66 C7+

GROUP TYPE	BY G.C.	BY FIA
SATURATES (P+N)	45.37	
OLEFINS (O)	7.85	
AROMATICS (A)	46.78	

D-SUBST. AROMATICS	
C 8	2.45
C 9+	6.25
TOTAL	8.70

METHYL SUBSTITUTED AROMATICS 42.43, ALKYLATE C-8 ISOPARAFFINS 0.0

DIOLEFINS, LV% 0.0

SP. GRAV. (60/60) 0.7620
API 54.21
MEASURED VALUES

CARBON/HYDROGEN RATIO, CALC. 7.1013 , MEAS.

STOICHIOMETRIC AIR/FUEL RATIO = 14.29 LBS AIR / LB FUEL

FUEL 008527 DETAILED COMPOSITION

CRC-CTF-2

CARB. NUMB.	NORMAL PARAFFIN	ISO-PARAFFIN	NAPH - THENES	OLEFINS	AROMATIC AR. AR+	UNCLASS. HC	TOTALS	CYCLO-PENTANES	CYCLO-HEXANES
3	0.06	******	******	0.0	******	******	0.06	******	******
4	2.56	0.50	******	0.43	******	******	3.48	******	******
5	2.77	20.04	0.17	4.20	******	******	27.17	0.17	******
6	0.50	2.47	0.78	2.20	0.56	******	6.51	0.67	0.11
7	1.48	2.65	1.32	1.10	21.39	******	27.95	1.05	0.28
8	0.98	4.40	1.17	0.09	11.04	0.05	17.74	0.91	0.26
9	0.43	2.26	0.02	0.0	9.10	0.37	11.19	0.02	0.0
10	0.21	0.47	0.0	0.0	3.06	0.69	4.44	0.0	0.0
11	0.13	0.20	0.0	0.0	0.90	0.16	1.38	0.0	0.0
12	0.08	0.0	0.0	0.0	0.0	0.0	0.08	0.0	0.0
TOTAL	9.19	33.00	3.47	8.01	45.06	1.27	100.00	2.82	0.65

SUBGROUPS					
LT	5.88 C3-6	23.00 C4-6	0.95 C5-6	6.82 C3-6	33.00 C6-8
HY	3.31 C7+	10.05 C7+	2.52 C7+	1.19 C7+	12.06 C9+

ISO-PAR +NAPHTH		
	LT	23.95 C4-6
	HY	12.56 C7+

GROUP TYPE	BY G.C.	BY FIA
SATURATES (P+N)	46.93	
OLEFINS (O)	8.01	
AROMATICS (A)	45.05	

O-SUBST. AROMATICS	
C 8	2.37
C 9+	5.80
TOTAL	8.16

METHYL SUBSTITUTED AROMATICS 40.43, ALKYLATE C-8 ISOPARAFFINS 0.30

DIOLEFINS, LV% 0.02

SP. GRAV. (60/60) 0.7603
API 54.61
MEASURED VALUES

CARBON/HYDROGEN RATIO, CALC. 7.0287 , MEAS.

STOICHIOMETRIC AIR/FUEL RATIO = 14.31 LBS AIR / LB FUEL

FUEL 007066 DETAILED COMPOSITION

CRC-CTF-3

CARB. NUMB.	NORMAL PARAFFIN	ISO-PARAFFIN	NAPH - - THENES	OLEFINS	AROMATIC AB. BN.	UNCLASS. HC	TOTALS	CYCLO-PENTANES	CYCLO-HEXANES
3	0.02	******	******	0.0	******	******	0.02	******	******
4	0.65	0.32	******	0.02	******	******	0.98	******	******
5	2.28	18.53	0.21	0.04	******	******	21.06	0.21	******
6	1.08	11.14	2.61	0.0	0.08	******	14.90	2.29	0.32
7	0.28	5.78	2.34	0.0	0.03	******	8.43	1.62	0.72
8	0.01	35.81	0.31	0.08	1.98	0.0	38.20	0.25	0.06
9	0.11	3.91	0.0	0.0	7.21	0.74	11.96	0.0	0.0
10	0.30	0.51	0.0	0.0	0.82	1.74	3.36	0.0	0.0
11	0.22	0.23	0.0	0.0	0.01	0.62	1.08	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	4.94	76.23	5.47	0.13	10.12	3.10	100.00	4.37	1.09

SUBGROUPS

LT	4.03 C3-6	29.98 C4-6	2.82 C5-6	0.05 C3-6	2.09 C6-8
HY	0.91 C7+	46.25 C7+	2.65 C7+	0.08 C7+	8.03 C9+

ISO-PAR	LT	32.80 C4-6
+NAPHTH	HY	48.89 C7+

GROUP TYPE	BY G.C.	BY FIA	O-SUBST. AROMATICS	
SATURATES (P+N)	89.74		C 8	1.84
OLEFINS (O)	0.13		C 9+	2.67
AROMATICS (A)	10.12		TOTAL	4.51

METHYL SUBSTITUTED AROMATICS 8.43, ALKYLATE C-8 ISOPARAFFINS 22.59

DIOLEFINS, LV% 0.0

SP. GRAV. (60/60) 0.7047
API 69.29
MEASURED VALUES

CARBON/HYDROGEN RATIO, CALC. 5.5663 , MEAS.

STOICHIOMETRIC AIR/FUEL RATIO = 14.94 LBS AIR / LB FUEL

CRC-CTF-4

FUEL 006330 DETAILED COMPOSITION

CARB. NUMB.	NORMAL PARAFFIN	ISO-PARAFFIN	NAPH - THENES	OLEFINS	AROMATIC AR. HC+	UNCLASS. HC	TOTALS	CYCLO-PENTANES	CYCLO-HEXANES
3	0.0	******	******	0.0	******	******	0.0	******	******
4	0.40	0.15	******	0.38	******	******	0.93	******	******
5	1.36	7.48	0.40	5.24	******	******	14.49	0.40	******
6	1.43	9.03	4.09	4.92	0.73	******	20.19	3.46	0.63
7	0.99	6.01	6.07	2.80	9.39	******	25.25	4.40	1.68
8	0.22	2.54	2.75	0.25	5.40	0.41	11.57	2.13	0.63
9	0.18	1.70	0.07	0.0	11.13	0.92	14.00	0.07	0.0
10	0.21	0.51	0.0	0.0	7.52	1.16	9.39	0.0	0.0
11	0.17	0.60	0.0	0.0	3.12	0.29	4.18	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	4.96	28.01	13.39	13.59	37.27	2.77	100.00	10.45	2.94

SUBGROUPS					
LT	3.19 C3-6	16.65 C4-6	4.49 C5-6	10.54 C3-6	15.51 C6-8
HY	1.77 C7+	11.77 C7+	8.90 C7+	3.05 C7+	21.76 C9+

ISO-PAR +NAPHTH		
	LT	21.15 C4-6
	HY	20.66 C7+

GROUP TYPE	BY G.C.	BY FIA
SATURATES (P+N)	49.14	
OLEFINS (O)	13.59	
AROMATICS (A)	37.27	

O-SUBST. AROMATICS	
C 8	1.38
C 9+	10.73
TOTAL	12.11

METHYL SUBSTITUTED AROMATICS 30.93, ALKYLATE C-8 ISOPARAFFINS 0.0

DIOLEFINS, LV% 0.0

SP. GRAV. (60/60) 0.7673

API 52.92

MEASURED VALUES

CARBON/HYDROGEN RATIO, CALC. 6.7745 , MEAS.

STOICHIOMETRIC AIR/FUEL RATIO = 14.41 LBS AIR / LB FUEL

FUEL 00H313 DETAILED COMPOSITION

CRC-CTF-5

CARB. NUMB.	NORMAL PARAFFIN	ISO-PARAFFIN	NAPH - - THENES	OLEFINS	AROMATIC AB. BN+	UNCLASS. HC	TOTALS	CYCLO-PENTANES	CYCLO-HEXANES
3	0.61	******	******	0.06	******	******	0.66	******	******
4	4.05	0.91	******	1.42	******	******	6.37	******	******
5	3.46	7.78	0.46	3.61	******	******	15.31	0.46	******
6	2.15	7.51	1.87	2.27	1.42	******	15.23	1.63	0.25
7	1.25	6.78	1.77	1.04	4.81	******	15.64	1.46	0.31
8	0.69	12.36	1.24	0.14	8.08	0.01	22.51	0.95	0.29
9	0.43	2.31	0.25	0.0	8.71	0.63	12.33	0.25	0.0
10	0.25	1.06	0.0	0.0	4.93	2.03	8.27	0.0	0.0
11	0.03	0.31	0.0	0.0	2.74	0.58	3.67	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	12.92	39.03	5.58	8.53	30.68	3.25	100.00	4.74	0.85

SU-GROUPS					
LT	10.27 C3-6	16.20 C4-6	2.33 C5-6	7.35 C3-6	14.30 C6-8
HY	2.65 C7+	22.84 C7+	3.25 C7+	1.18 C7+	16.38 C9+

ISO-PAR +NAPHTH		
	LT	18.53 C4-6
	HY	26.09 C7+

GROUP TYPE	BY G.C.	BY FIA
SATURATES (P+N)	60.78	
OLEFINS (O)	8.53	
AROMATICS (A)	30.68	

O-SUBST. AROMATICS	
C 8	1.97
C 9+	7.42
TOTAL	9.39

METHYL SUBSTITUTED AROMATICS 22.90, ALKYLATE C-- ISOPARAFFINS 6.61

DIOLEFINS, LV% 0.0

SP. GRAV. (60/60) 0.7430
API 58.94
MEASURED VALUES

CARBON/HYDROGEN RATIO, CALC. 6.4134 , MEAS.

STOICHIOMETRIC AIR/FUEL RATIO = 14.55 LBS AIR / LB FUEL

CRC-CTF-6

FUEL 007065 DETAILED COMPOSITION

CARB. NUMB.	NORMAL PARAFFIN	ISO-PARAFFIN	NAPH - - THENES	OLEFINS	AROMATIC AR, BN+	UNCLASS. HC	TOTALS	CYCLO-PENTANES	CYCLO-HEXANES
3	0.02	******	******	0.0	******	******	0.02	******	******
4	7.21	0.45	******	1.29	******	******	8.95	******	******
5	3.34	8.18	2.05	3.79	******	******	17.35	2.05	******
6	2.72	8.81	6.80	2.01	0.51	******	20.85	5.59	1.20
7	1.08	9.73	3.67	0.48	2.63	******	17.59	2.62	1.06
8	0.44	9.02	1.10	0.01	6.84	0.0	17.41	0.92	0.18
9	0.26	1.81	0.0	0.0	7.48	0.54	10.09	0.0	0.0
10	0.17	0.72	0.0	0.0	4.08	0.81	5.77	0.0	0.0
11	0.20	0.66	0.0	0.0	0.85	0.26	1.96	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	15.43	39.38	13.61	7.58	22.39	1.61	100.00	11.18	2.43

SUBGROUPS					
LT	13.28 C3-6	17.44 C4-6	8.84 C5-6	7.09 C3-6	9.98 C6-8
HY	2.14 C7+	21.93 C7+	4.77 C7+	0.49 C7+	12.41 C9+

ISO-PAR +NAPHTH		
LT	26.28	C4-6
HY	26.70	C7+

GROUP TYPE	BY G.C.	BY FIA
SATURATES (P+N)	70.02	
OLEFINS (O)	7.58	
AROMATICS (A)	22.39	

O-SUBST. AROMATICS	
C 8	1.57
C 9+	6.03
TOTAL	7.60

METHYL SUBSTITUTED AROMATICS 18.24, ALKYLATE C-8 ISOPARAFFINS 4.46

DIOLEFINS, LV% 0.0

SP. GRAV. (60/60) 0.7263
API 63.32
MEASURED VALUES

CARBON/HYDROGEN RATIO, CALC. 6.0946 , MEAS.

STOICHIOMETRIC AIR/FUEL RATIO = 14.69 LBS AIR / LB FUEL

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